Journal of the Institute of Petroleum

THE UNIVERSITY OF MICHIGAN
SEP 27 1960
ENGINEERING LIBRARY

VOL. 46 AUGUST 1960 No. 440

CONTENTS

239 **Annual Report for 1959**

249 **Forty-seventh Annual General Meeting**

252 **Petroleum People—Planning for To-morrow**
By C. M. Vignoles, C.B.E.

259 **The Effect of Additives on the Water-Induced Pitting of Ball Bearings**
By L. Grunberg and D. Scott

267 **Thermal Conductivity Measurements on Oils**
By R. W. Powell and A. R. Challoner

272 **IP Standards**

Abstracts 1082–1230

Book Reviews

PRICE 10s 0d A COPY OR
£4-14-6 YEARLY *POST FREE*

Published by the Institute of Petroleum 61 New Cavendish Street London W1

Printed in Great Britain by Richard Clay and Company Ltd Bungay Suffolk

COUNCIL, 1960–61

President

J. M. Leonard, M.I.Chem.E.

Immediate Past-President

C. M. Vignoles, C.B.E., M.A.

Vice-Presidents

C. Chilvers, B.Sc., F.R.I.C. T. W. Mathias, O.B.E., M.A.

Members of Council

J. G. Annan, B.Sc.
W. S. Ault, B.A.
V. Biske, B.Sc., LL.M., F.R.I.C.
G. Chandler, M.A.
E. J. Dunstan, M.Sc., M.I.Chem.E.
A. J. Foster
T. F. Gaskell, M.A., Ph.D., F.R.A.S.
Sir Stephen Gibson, C.B.E., M.A., M.I.Mech.E.
R. H. W. Hamilton, M.A.
L. L. Hosking, B.E., M.I.C.E., A.M.N.Z.I.E.
M. E. Hubbard, B.A., M.I.Mech.E.
W. E. Madden, A.R.S.M.
C. S. Newey, B.Sc.
J. S. Parker, M.A., B.Sc.
W. H. Thomas, A.R.S.M., F.R.I.C.

Representing the Branches Committee

C. W. Banyard, B.Sc.(Eng.) J. H. M. Clark, T.D., A.C.A.
H. Kaye, B.Sc., A.M.I.Chem.E.

Honorary Treasurer

O. F. Thompson, O.B.E.

Honorary Secretary

G. A. Dickins, B.Sc.(Hons), F.R.I.C., M.Am.Chem.Soc.

Honorary Editor

E. B. Evans, M.Sc., Ph.D., F.R.I.C.

Honorary Associate Editor

D. L. Samuel, B.Sc., A.R.I.C.

General Secretary

D. A. Hough, T.D., F.I.A.C.

Editor

George Sell

Honorary Secretaries of Branches

Bahrain Branch: D. G. Johnstone, c/o Bahrain Petroleum Co. Ltd., Awali, Bahrain, Persian Gulf.

Essex Branch: D. Rawlinson, F.R.I.C., c/o Shell Refining Co. Ltd., Shell Haven, Essex.

Fawley Branch: C. W. Banyard, B.Sc.(Eng.), c/o Esso Petroleum Co. Ltd., Fawley, Southampton.

Kuwait Branch: G. A. Lee, c/o Kuwait Oil Co. Ltd., Ahmadi, Kuwait.

London Branch: J. H. M. Clark, T.D., A.C.A., c/o Mobil Oil Co. Ltd., Caxton House East, Westminster, S.W.1.

Northern Branch: H. Kaye, B.Sc., A.M.I.Chem.E., c/o Manchester Oil Refinery Ltd., Twining Road, Trafford Park, Manchester 17.

Scottish Branch: W. M. Stirling, A.H-W.C., A.M.I.E.E., Scottish Oils Ltd., Middleton Hall, Uphall, Broxburn, W. Lothian.

South-Eastern Branch: D. K. L. Morgan, B.Sc., c/o BP Refinery (Kent) Ltd., Isle of Grain, Rochester, Kent.

South Wales Branch: G. L. Jenkins, BP Refinery (Llandarcy) Ltd., Llandarcy, Glam.

Stanlow Branch: A. S. Brooman, B.Sc., 11 Grange Crescent, Hooton, Wirral, Cheshire.

Trinidad Branch: W. G. Poole, B.Sc., A.R.S.M., F.G.S., c/o Texaco Trinidad Inc., Forest Reserve, Fyzabad, Trinidad, B.W.I.

Yorkshire Branch: A. Furness, c/o J. W. Miller and Son Ltd., Hillside Oil Works, Brighouse, Yorks.

THE INSTITUTE OF PETROLEUM

ANNUAL REPORT

For the Year Ending 31 December 1959

General

The year 1959 has been a very busy one for the Institute, with the 5th World Petroleum Congress taking place in New York in June, and a new Group covering Exploration and Production being formed in the autumn, with an initial membership of over 120.

The World Petroleum Congresses started in London in 1933, and the Secretariat of the Permanent Council has always been provided by the Institute of Petroleum. The 5th Congress in New York was very well supported by the Institute, and over 200 members and their wives attended the Congress. The Institute of Petroleum bureau and lounge became a focal point and meeting place for most of the British delegates.

During the year the Institute's membership passed 4000.

Honours

The Council offers its congratulations to the following members of the Institute who were honoured by Her Majesty the Queen during the year:

R. J. Pinder . . .	C.B.E.
C. V. Hill	O.B.E.
J. J. Page	O.B.E.

Awards

During the year Sir Reginald Ayres, K.B.E., C.B., and Sir Leonard Sinclair were awarded the Honorary Membership of the Institute, and Mr J. A. Oriel, C.B.E., M.C. and Sir Philip Southwell, C.B.E., M.C. were awarded Honorary Fellowships.

Mr C. Chilvers was awarded the Eastlake Medal for his long and meritorious service to the Institute as Honorary Secretary.

General Meetings

Nine General Meetings were held during the year, and attendances remained satisfactory.

Redwood Medal

In December, at a very well attended meeting, Mr A. C. Hartley, C.B.E., delivered his Lecture entitled " Pipelines " and received the Redwood Medal from the President.

Annual Dinner

The Guest of Honour at the Annual Dinner, held once again at Grosvenor House, was The Right Honourable Lord Mills, K.B.E., The Minister of Power. Over 1450 members and their guests attended the function.

Studentship

The Institute's Annual Prize at the Imperial College of Science and Technology was awarded to Mr T. G. King, and Mr D. I. Lloyd received the Institute's annual Scholarship award at Birmingham University.

Honorary Secretary and Honorary Treasurer

After both had held office for twelve most successful years, Mr C. Chilvers retired from the Honorary Secretaryship and Mr G. H. Coxon retired from the Honorary Treasurership in April.

Mr W. M. Catchpole became the new Honorary Secretary, and the new Honorary Treasurer is Mr O. F. Thompson, O.B.E.

Branches

The Institute's twelve Branches have continued to flourish throughout the year. The new Yorkshire Branch has been firmly established in Leeds, and reports of meetings show increased attendances over the previous year. Mr G. H. Thornley retired from the Chairmanship of the Branches Committee after twelve years' outstanding service.

Economics and Operations Group

The Economics and Operations Group continued to hold monthly meetings during the winter months, and

was fortunate in obtaining some most interesting papers.

There were five meetings with an average attendance of over sixty.

Education

As a result of the efforts of the Committee, and particularly of certain members thereof, the syllabus for the City and Guilds Petroleum Courses has now been revised. As a first stage there will now be a course particularly suitable for petroleum plant operators. Much of the syllabus will be similar to that for chemical plant operators, with certain special sections designed for the petroleum industry.

The Chairman and a member of the Committee have been asked to become members of the City and Guilds Advisory Committee on Petroleum and Petroleum Products.

The Committee keeps a watching brief on various courses connected with the oil industry. The course on " Distribution of Oil," which has been given yearly at the Sir John Cass College, has proved so successful that the Committee arranged for it to be repeated at the Manchester College of Science and Technology in April 1959.

Arrangements were also made for an annual lecture to be given at the Science Museum on Petroleum Chemicals designed for 6th form students. Lecturers for the next three years were nominated.

Engineering

After fourteen years of outstanding services as Chairman, Mr E. J. Sturgess, C.B.E., relinquished his position at the beginning of 1959, these duties being taken over by Mr L. L. Hosking.

Towards the end of the year the Production Sub-Committee was re-formed. It is actively engaged in revising the IP Drilling and Production Safety Code. Its membership includes representatives from Drilling Contractors.

It has now been decided to publish the Airfield Safety Code, not as a supplement to the IP Marketing Safety Code, but as a separate document—Part VI of the IP Safety Codes. It is expected that both Codes will be ready for publication in 1960.

The Safety Sub-Committee has continued to hold useful meetings, one of which took place at a Fire Fighting Equipment Manufacturer's works.

The advice of the Committee was sought by the Home Office in connexion with their Model Code Part III, and as in previous years, a considerable number of technical enquiries from both this country and abroad have been answered.

Publications

The 45th volume of the *Journal*, and the 13th volume of the *IP Review* were completed during 1959, although there was some delay in publication of the later issues due to the effect of the withdrawal of labour in the printing industry. In each case there was again an increase in the number of copies circulated both to members and to subscribers, thus reflecting the value which the industry places upon these publications. The only new book publication during the year was the 18th edition of " Standard Methods," but it was found necessary to produce reprints of three of the safety codes, these being the Tanker Code, the Electrical Code, and the Marketing Code. Also the ASTM/IP Petroleum Measurement Tables continued to be sought, and reprints of the metric and British editions were called for during 1959.

Work started during the year on the third edition of " Modern Petroleum Technology," and the opportunity has been taken to recast the contents to meet up-to-date requirements.

Standardization

The reorganization of Sub-Committees and panels mentioned in the report for 1958 has now been carried out. This has resulted in reducing the membership of the main Committee from 43 to 33, the number of the Sub-Committees from 15 to 10, and the number of Panels from 49 to 47. Details are given in an article in the *Review* for February 1960.

In future, "Standard Methods" will be issued in four parts, covering methods for analysis and testing (Part I), engine tests for fuels (Part II), engine tests for crankcase oils (Part III), and sampling (Part IV). Part I, which is due for publication in March 1960, will include 1 new method and revisions to 12 existing methods; one method has been withdrawn. It is hoped that Parts II and III can be published before the end of 1960. Part IV is due for publication about the same time as Part I.

The valuable co-operation of Member Companies in allowing their technical specialists to take an active part in this important aspect of the work of the Institute is gratefully acknowledged by Council.

Active co-operation with the British Standard Institution and with foreign standardizing bodies has continued.

Research

The Hydrocarbon Research Group has continued its support of research work at various universities and colleges.

The Gas Chromatography Discussion Group, which started in an informal way after the Symposium in 1956, has since been very active in promoting the use of gas chromatography as an analytical tool, especially in the petroleum industry. The relationship between this Discussion Group and the Hydrocarbon Research Group has now been defined on a permanent basis, and the annual accounts of the Hydrocarbon Research

Group will in future incorporate those of the Gas Chromatography Discussion Group.

Co-operation continues with the Medical Research Council.

Staff

The staff of the Institute have continued to provide excellent service and have met all demands made upon them during a year made more arduous by the World Petroleum Congress and a strike in the printing industry. It was unfortunate that during the year the library was without staff for several months. We have now been able to rectify the position, and the library is once again providing a useful service, both to members of the Institute and those desiring information regarding petroleum and its products.

MEMBERSHIP

Details of Membership as at 31 December 1959:

	Total 31 Dec. 1958	Changes during 1958						Total 31 Dec. 1959
		New	Transferred to	Resigned	Deceased	Transferred from	+ or −	
Honorary Members	2	1	1	—	—	—	+ 2	4
Honorary Fellows	6	—	2	—	—	—	+ 2	8
Members	670	33	10	32	9	4	− 2	668
Fellows	803	38	15	21	12	4	+ 16	819
Associate Members	846	42	—	37	3	14	− 12	834
Associate Fellows	1517	200	8	60	11	8	+129	1646
Students	47	14	—	3	—	6	+ 5	52
Totals	3891	328	36	153	35	36	+140	4031
Member Companies	234	7	—	6	—	—	+ 1	235

DEATHS

It is with regret that the following deaths during 1959 are recorded:

A. R. Bowen (F)
J. M. Bownes (AF)
S. C. R. Cooper (AF)
D. Donoghue (M)
H. G. Freeston (AF)
J. L. E. Groff (F)
J. Haker (M)
C. Hargreaves (F)
F. Hawes (AF)
W. R. Hodgson (AF)
G. W. D. Holmes (AM)
E. L. P. Huguin (F)
E. N. Humphries (AF)
R. C. Jennings (M)
B. E. F. Lillie (M)
K. W. MacNee (M)
P. Marks (AF)
A. Morrison (F)
J. A. Morrison (M)
G. R. Nixon (F)
G. W. I. Nokes (AM)
W. J. Peirce (M)
E. P. Pink (AM)
H. J. Rudge (AF)
A. J. Ruthven-Murray (F)
W. P. Ryce (AF)
H. G. Shatwell (M)
G. W. Smith (AF)
H. A. Stewart (M)
I. A. Stigand (F)
R. K. Stratford (F)
A. J. Thomson (M)
G. H. Titchmarsh (F)
C. M. White (AM)
W. J. Wigney (F)

A. J. Ruthven-Murray was a member of the Institute for 36 years and served on Council from 1953 until 1959. R. K. Stratford represented Canada on the Permanent Council of the World Petroleum Congress from 1950 until his death. W. G. Wigney had been a member for over forty years, and I. A. Stigand joined the Institute in 1913, the year of its foundation. A. R. Bowen, D. Donoghue, and H. G. Shatwell had all been members of the Institute for over thirty years.

By Order of the Council,
W. M. CATCHPOLE,
Honorary Secretary

March 1960

THE INSTITUTE

(A Company limited by Guarantee

BALANCE SHEET AS

1958 £	£		£ s. d.	£ s. d.	£ s. d.
		Capital of the Institute under Bye-Laws 36, 44, and 45:			
		Life Membership Fund—			
1,149		As at 31 December 1958		1,148 19 0	
		Entrance and Transfer Fees—			
		As at 31 December 1958	9,023 6 9		
		Add Receipts during 1959:			
		Entrance Fees	407 8 0		
		Transfer Fees	21 0 0		
9,023				9,451 14 9	
		General Donations—			
331		As at 31 December 1958		331 5 0	
		Special Donations Building Fund Account—			
91,010		As at 31 December 1958		91,009 11 0	
101,513				101,941 9 9	
		Investment Reserve—			
		Net Surplus on Realization of Investments	480 3 2		
(deduct) *291*		*Less* Net Loss on Sale of Investments brought forward	291 9 9		
				188 13 5	
101,222					102,130 3 2
		General Reserve:			
1,702		As at 31 December 1958		20,000 0 0	
18,298		*Add* Transfer from Revenue Account		5,000 0 0	
20,000					25,000 0 0
500		**Reserve for General Repairs and Maintenance**			1,000 0 0
		Revenue Account:			
47,470		As at 31 December 1958		30,081 11 10	
5,910		*Add* Surplus for year		— — —	
53,380				30,081 11 10	
		— *Deduct* Deficit for year	515 17 9		
	18,298	Transfer to General Reserve	5,000 0 0		
	5,000	Amount written off Leasehold Premises	5,000 0 0		
	23,298			10,515 17 9	
30,082					19,565 14 1
		Subscriptions Received in Advance:			
		Members' Subscriptions for 1960		2,099 8 6	
		Members' Subscriptions for 1961		13 18 8	
		Members' Subscriptions for 1962		4 4 0	
		Member-Company Subscriptions for 1960		260 5 0	
		Journal Subscriptions for 1960		2,986 12 7	
		Journal Subscriptions for 1961		29 8 0	
		Journal Subscriptions for 1962		12 9 5	
5,536					5,406 6 2
		Current Liabilities and Provisions:			
350		Provision for Pension		350 0 0	
14,113		Sundry Creditors and Accrued Charges		7,921 1 5	
1,368		World Petroleum Congress		803 7 2	
1,045		Fuel Testing Correlation Fund		875 19 2	
935		Entertainment Account		264 1 10	
17,811					10,214 9 7
£175,151					**£163,316 13 0**

AUDITORS' REPORT TO THE MEMBERS

We have examined the above Balance Sheet and annexed Revenue Account and report that we have obtained all the In our opinion, proper books of account have been kept by the Institute, so far as appears from our examination of those best of our information and according to the explanations given to us, the accounts give the information required by the affairs at 31 December 1959, and the Revenue Account gives a true and fair view of the revenue for the year ended on that

SCOTTISH UNION HOUSE,
25 BUCKLERSBURY,
LONDON, E.C.4.
23 *February* 1960.

OF PETROLEUM

and not having a Share Capital)

AT 31 DECEMBER 1959

1958 £	£		£	s.	d.	£	s.	d.
		Leasehold Premises (997 years unexpired):						
19,999		Cost of acquisition in 1955	19,998	10	0			
90,787		*Add* Cost of conversion	90,787	8	1			
110,786			110,785	18	1			
5,000		*Less* Amounts written off	10,000	0	0			
105,786						100,785	18	1
		Office and Library Furniture:						
		At valuation, being Net Amount in the Company's books at 1 July 1948,						
221		*less* Sales	221	10	8			
11,182		At cost	11,667	14	10			
11,403			11,889	5	6			
2,491		*Less* Aggregate Depreciation	4,868	17	5			
8,912						7,020	8	1
		Investments—at Cost (Per Schedule I):						
22,422		(Market Value at 31 December 1959 £37,939; 1958 £22,438)				34,196	13	1
		Current Assets:						
5,806		Stock of Publications as certified by the General Secretary	3,240	0	0			
7,707		Sundry Debtors and Payments in Advance, including Tax recoverable	7,532	13	4			
—		Members' Subscriptions in arrear—not valued	—	—	—			
2,011		Member-Company Subscriptions in arrear	31	10	0			
7,500		Loan—Birkenhead Corporation	—	—	—			
439		Cash on Deposit with Post Office Savings Bank	450	3	3			
		Balance at Bank—						
	£		£	s.	d.			
	7,520	Deposit Account	520	0	0			
	6,382	Current Accounts	8,939	7	2			
13,902			9,459	7	2			
600		Cash in Hand	600	0	0			
37,965						21,313	13	9
66		**Assets Held on Account of the Building Fund**				—	—	—

Note: The total of the bank balances held by the Institute's Branches but excluded from the above, as at 31 December 1959 was £1,260 8*s.* 10*d.*

£175,151	£163,316 13 0

OF THE INSTITUTE OF PETROLEUM

information and explanations which to the best of our knowledge and belief were necessary for the purposes of our audit. books. The Balance Sheet and Revenue Account are in agreement with the books of account. In our opinion, and to the Companies Act, 1948, in the manner required, and the Balance Sheet gives a true and fair view of the state of the Institute's date.

(*Signed*) SMITH & WILLIAMSON,

Chartered Accountants.
Auditors.

THE INSTITUTE

(A Company limited by Guarantee

REVENUE ACCOUNT FOR THE

1958 £	£		£ s. d.	£ s. d.
		To Administrative Expenses:		
		Staff (Other than Publications)—		
	7,543	Salaries and National Insurance	7,892 14 8	
	821	Staff Pension Scheme Contributions	838 13 9	
8,364				8,731 8 5
		(*Note:* Total Salaries £15,146 6*s.* 8*d.*; Total Pension Contributions Contributions £1,662 1*s.* 8*d.*)		
	1,940	Printing and Stationery	1,731 13 3	
	1,677	General Postages	1,322 15 8	
	509	Telephone, Cables, and Travelling Expenses	535 9 9	
	4,026		3,589 18 8	
	1,342	*Less* Applicable to Publications—one-third	1,196 12 11	
2,684				2,393 5 9
	95	Audit Fee	94 10 0	
	297	General Expenses	288 3 11	
	201	Insurances	215 16 10	
	120	Printing of Memorandum, Articles of Association, and Bye-Laws	— — —	
713				598 10 9
11,761				11,723 4 11
		„ **Establishment Expenses:**		
	572	Rent and Water Rates	557 13 0	
	573	Cleaning	616 17 8	
	661	Gas and Electricity	485 7 5	
	295	Heating	205 1 7	
	76	Repairs and Maintenance	99 14 5	
	2,177		1,964 14 1	
	544	*Less* Applicable to Publications—one-third	654 18 0	
1,633				1,309 16 1
		„ **Meetings:**		
528		Pre-prints, Reporting, etc.		571 8 4
636		„ **Grants to Branches**		715 0 0
		„ **Sundries:**		
	396	Library Expenses	306 17 6	
	7	Legal Expenses	362 19 2	
	114	Subscriptions to Societies	112 8 1	
	100	Scholarship Awards	100 0 0	
617				882 4 9
990		„ **Depreciation of Furniture**		2,377 17 1
—		„ **5th World Petroleum Congress**		3,784 19 7
		„ **Publications:**		
		Production and Distribution	30,658 3 7	
		Salaries, National Insurance, and Pension Scheme Contributions	8,076 19 11	
		Proportion (one-third) of Administrative and Establishment Expenses	1,851 10 11	
			40,586 14 5	
		Advertising Revenue	20,168 9 10	
		Sales	16,909 17 9	
			37,078 7 7	
2,530		Deficit		3,508 6 10
18,695				24,872 17 7
500		„ **Transfer to Reserve for General Repairs and Maintenance**		500 0 0
5,910		„ **Balance, being Surplus Revenue for Year**		— — —
£25,105				£25,372 17 7

OF PETROLEUM

and not having a Share Capital)

YEAR ENDED 31 DECEMBER 1959

1958		£	*s.*	*d.*
12,644	By Members' Subscriptions received for 1959	13,239	1	0
285	„ Members' Subscriptions in arrear, received during year	145	1	0
10,417	„ Member-Company Subscriptions received for 1959	10,259	19	6
20	„ Special Subscription	20	0	0
1,739	„ Interest and Dividends Received (Gross)	1,192	18	4
—	„ Balance, being Deficit for Year	515	17	9
£25,105		£25,372	17	7

HYDROCARBON RESEARCH GROUP

Revenue Account for the Year ended 30 September 1959

	£	s.	d.	£	s.	d.
To **Stock in Hand of " Molecular Spectroscopy "**				85	1	0
„ **Grants:**						
Imperial College of Science and Technology	1,097	11	9			
King's College	1,460	0	0			
Queen Mary College	1,780	0	0			
University of Bristol	500	0	0			
University of Cambridge	600	0	0			
University of Edinburgh	400	0	0			
University of Glasgow	260	0	0			
University of Oxford	1,700	0	0			
				7,797	11	9
„ **Honoraria**				420	0	0
„ **Preprints and Reports**				155	9	3
„ **General Expenses**					10	0
„ **Salaries**				350	0	0
„ **Balance, being Surplus Revenue for year**				583	1	6
				£9,391	13	6

	£	s.	d.
By **Voluntary Contributions from Members of the Group**	9,000	0	0
„ **Sales of " Molecular Spectroscopy "**	123	18	0
„ **Symposium on Molecular Spectroscopy**	245	14	6
„ **Stock in Hand of " Molecular Spectroscopy "**	22	1	0
	£9,391	13	6

Notes:

(i) For convenience in administration, the Accounts of the Group are closed as at 30 September each year.

(ii) The Group are now liable to bear all losses incurred in connection with their publications.

Statement of Funds as at 30 September 1959

	£	s.	d.	£	s.	d.
Revenue Account:						
As at 30 September 1958	1,690	11	11			
Add Surplus for year	583	1	6			
				2,273	13	5
Sundry Creditor—The Institute of Petroleum				262	10	0
				£2,536	3	5

	£	s.	d.
Stock in Hand of " Molecular Spectroscopy "	22	1	0
Balance at Bank on Current Account	2,514	2	5
	£2,536	3	5

We have examined the above Revenue Account and Statement of Funds with the books and vouchers of the Group and find them to be in accordance therewith.

Scottish Union House,
25 Bucklersbury,
London, E.C.4.
23 *February* 1960.

(*Signed*) Smith & Williamson,
Chartered Accountants.
Auditors.

CARCINOGENICITY RESEARCH FUND

Statement of Funds as at 31 December 1959

	£	s.	d.		£	s.	d.
Balance of Sum Received from the Petroleum Board (during 1947):				**Balance at Bank on Current Account**	304	0	8
As at 1 January 1959	302	17	0				
Accumulated Net Income:							
As at 1 January 1959	1	3	8				
	£304	0	8		£304	0	8

We have examined the above Statement of Funds with the books and vouchers of the Fund and find it to be in accordance therewith.

Scottish Union House,
25 Bucklersbury,
London, E.C.4.
23 *February* 1960.

(*Signed*) Smith & Williamson
Chartered Accountants.
Auditors.

CADMAN MEMORIAL FUND

Income and Expenditure Account for the Year ended 31 December 1959

	£	s.	d.	£	s.	d.		£	s.	d.	£	s.	d.
To **Balance at 31 December 1959:**							By **Balance at 31 December 1958**	3,358	16	4			
Balance at Bank on Deposit Account	500	0	0				*Add* Interest Received (Gross)	91	17	11			
Balance at Bank on Current Account	220	14	3								3,450	14	3
£2,730 3% Savings Bonds 1965/75	2,730	0	0										
(Market Value—£2,116)				3,450	14	3							
				£3,450	14	3					£3,450	14	3

We have examined the above Income and Expenditure Account with the books and vouchers of the Fund and find it to be in accordance therewith.

Scottish Union House,
25 Bucklersbury,
London, E.C.4.
23 *February* 1960.

(*Signed*) Smith & Williamson,
Chartered Accountants.
Auditors.

Schedule I

THE INSTITUTE OF PETROLEUM

INVESTMENTS—31 DECEMBER 1959

	At Cost £	s.	d.	Market Value at 31 December 1959 £
£3,600 2½% Exchequer Stock 1963/64	3,359	1	4	3,366
£3,900 2½% Savings Bonds 1964/67	3,288	15	9	3,315
£3,800 3% Savings Bonds 1955/65	3,432	9	6	3,515
2,000 British Assets Trust Ltd. Ordinary 5*s*. Shares	1,977	0	6	2,800
£300 Edinburgh Investment Trust Ltd. Deferred Stock	1,563	18	6	1,650
500 Keystone Investment Co. Ltd. Ordinary Stock £1 Units	774	14	0	775
1,900 Mercantile Investment and General Trust Co. Ltd. Ordinary 5*s*. Shares	2,113	14	3	3,040
750 Pentland Investment Trust Ltd. Ordinary Stock £1 Units	2,151	11	3	2,531
500 Scottish American Investment Co. Ltd. "A" Ordinary £1 Shares	2,151	5	0	2,500
2,500 Scottish Northern Investment Ltd. Ordinary 5*s*. Shares	2,008	5	6	2,781
400 Second Scottish American Trust Co. Ltd. Ordinary Stock £1 Units	1,455	11	0	1,425
60 Royal Bank of Canada $10 Shares	2,025	9	6	1,810
60 First National City Bank of New York Common Shares	1,906	3	0	2,033
50 Florida Power and Light Co. Common Shares	970	4	0	1,014
13 International Business Machines Corpn. Common Shares	2,023	10	6	2,089
55 Morgan Guaranty Trust Co. of New York Common Shares	2,011	6	9	2,329
75 South Carolina Electric and Gas Corpn. Common Shares	983	12	9	966
	£34,196	13	1	£37,939

THE INSTITUTE OF PETROLEUM

FORTY-SEVENTH ANNUAL GENERAL MEETING

THE Forty-seventh Annual General Meeting of The Institute of Petroleum was held at 61 New Cavendish Street, London, W.1, on 11 May 1960, the chair being taken by the President, C. M. Vignoles, C.B.E.

The notice convening the meeting, the minutes of the previous Annual General Meeting, and the minutes of the Special General Meeting held on 7 October 1959 were read. The minutes were confirmed as a correct record and signed.

ELECTION OF OFFICERS FOR THE SESSION 1960–61

President

C. M. Vignoles: The Council have nominated Julian M. Leonard to be President for the 1960–61 Session. Mr Leonard has been actively associated with the petroleum industry since 1917, when he entered the old-established family business of Carless, Capel and Leonard, distillers of petroleum and coal tar naphthas and the pioneers and inventors of the name "petrol." Mr Leonard is now the managing director and deputy chairman. He has been a member of the Institution of Chemical Engineers for nearly 25 years and is now a past vice-president and a member of its Council; he has always shown a great interest in petroleum and coal tar refining, and in 1921 he joined the Society of Chemical Industry, and has always taken an active and prominent part in its affairs. He was chairman of the Chemical Engineering Group, and after being honorary treasurer from 1946 to 1955, he was appointed the Society's president for the years 1955–56 and 1956–57. As well as being a Fellow of our own Institute for a number of years, he is a member of many other learned societies and institutions, and a liveryman of the Worshipful Company of Apothecaries and of the Worshipful Company of Farmers.

Mr Leonard much regrets his inability to be present this afternoon, but, following an illness earlier in the year, he is now convalescing in the South of France. He has telegraphed his regrets at not being here and his profound appreciation of the honour of being nominated as your President.

I have much pleasure in nominating Julian M. Leonard as President for the ensuing session.

The nomination was seconded by G. A. Dickins and carried unanimously.

Honorary Treasurer

On the proposal of V. Biske, seconded by H. Hyams, O. F. Thompson, O.B.E., was unanimously elected as Honorary Treasurer for the session 1960–61.

Honorary Secretary

W. M. Catchpole proposed, and M. E. Hubbard seconded, the election of G. A. Dickins as Honorary Secretary for the session. This was carried unanimously.

Honorary Editor

The election of Dr E. B. Evans as Honorary Editor for the session 1960–61 was proposed by D. L. Samuel, seconded by R. H. W. Hamilton, and carried unanimously.

Members of Council

As the result of a ballot, Dr T. F. Gaskell, W. E. Madden, and W. H. Thomas were declared elected as Members of Council for a term of three years.

The Council's nomination of R. H. W. Hamilton to fill a casual vacancy on Council, under By-Law 75, was approved.

Ex-officio Member of Council

As D. H. Tullis has resigned his ex-officio membership of Council, H. Kaye had been nominated to serve in this capacity for the period 1960–62. On the proposal of the chairman, seconded by J. G. Annan, this was carried unanimously.

MEMBERS ELECTED OR TRANSFERRED

In accordance with the By-Laws, a list of all persons elected or transferred during the year 1959 was tabled.

REPORT OF COUNCIL

W. M. Catchpole, presenting the Report of the Council for the year 1959, said: The state of health of an Institute must be judged by its membership, as well as by its financial position. The number of members has continued to rise, and I think a 2½ per cent increase during the year is very satisfactory.

The Institute is passing through a period of change, when unfortunately we see the retirement of a number of people who have given it excellent service as committee chairmen. G. H. Thornley retired from his

chairmanship of the Branches Committee during this year, after 12 years service in that position, and E. J. Sturgess relinquished his duties as chairman of the Engineering Committee after 14 years.

The Institute has, as in the past, continued to support research at the universities through the Hydrocarbon Research Group; that is a very valuable contribution from the Institute to the people engaged in academic research.

Finally, the Institute has had some difficulty, due to the printing strike, in getting out the *Journal* and the *IP Review*, and I would like to pay tribute to the efforts of the editorial staff in now almost catching up with the delays.

We did have some difficulty due to lack of staff in the library, but we now have a first-class librarian and also a very capable assistant librarian. I hope that we shall see that the library service is even better in the years to come than it has been in the years past.

Personally, I would like to say what a pleasure it has been to work with the Institute staff. I very much regret having given the Institute such short service as its Honorary Secretary, and am glad to know that Mr Dickins is going to take over the post.

The adoption of the report was then seconded by G. A. Dickins and carried unanimously.

ACCOUNTS

O. F. Thompson, presenting the Accounts for 1959: The accounts of the Institute are in quite a healthy state. The total of our investments has increased from approximately £32,400 last year to £34,000. A fairly successful investment policy has been followed, and the present value of those investments stands at around £38,000. The General Reserve has been increased by another £5000, which now puts it at £55,000.

Regarding the Revenue Account loss for 1959 of £500, we would not have incurred this loss and would have shown quite a substantial profit but for an extraordinary item of expense in the form of our contribution of approximately £3800 to the World Petroleum Congress.

Our expenditure in 1959, both establishment and administrative, has decreased, and the income has been approximately maintained. In that connexion, a very important part of our income is in members' subscriptions, bringing in last year no less than £13,239. May I suggest that we do give further consideration to the possibility of suitably increasing our membership, possibly at a slightly faster rate. There are quite a number of people who are eligible for membership and are not members.

The adoption of the Accounts for the year 1959 was then proposed by Mr Thompson, seconded by J. G. Annan, and carried unanimously.

AUDITORS

On the proposal of O. F. Thompson, seconded by V. Biske, Messrs Smith and Williamson were reappointed auditors at a remuneration to be fixed by Council.

RETIRING OFFICERS

H. Hyams: I am sure that all our members would wish to express to you, Mr Vignoles, their appreciation and thanks for the way in which you have guided the affairs of the Institute during your period of office. It is no light undertaking for a leader of the petroleum industry to-day to accept nomination for this office, and I think we were most fortunate that you were able to accept the office at the time when our new Constitution was coming into being. You have given freely of your wisdom and experience, which have been invaluable to the Institute at this time; and you have also carried out your official duties most faithfully, if I may say so. You have attended and presided regularly over our Council Meetings, and over the Ordinary General Meetings of the Institute. And I am sure all members present, and all members of the Institute, would like to thank you for what you have done for us.

C. M. Vignoles: Thank you for your recognition of what I have tried to do. It has been two very happy years for me. Certainly, there is quite a lot of work, but it has been made extremely pleasurable for me by the friendly and ever-ready support of the Council, and by the other members of the Institute who have shown their keenness by attending our meetings and generally supporting our work.

I would like to draw attention to the working of the new Constitution, in so far as it has resulted this year in a number of retirements from Council, and there are people whom I would like to mention. First of all, Lord Geddes, who retires from the Council under the Constitution. Nobody can underrate the contribution that he has made, first as President, when he was the architect of the new arrangements, and secondly, in the last two years, by the support he has given as chairman of the Finance General Purposes Committee.

Then we have a vice-president and a member of Council who have been with us since 1948—H. Hyams and D. L. Samuel—both of whom have given tremendous service in their time. Mr Hyams was vice-president and a former chairman of the Finance Committee, and has done invaluable work in many directions, and Mr Samuel has been our honorary associate editor and has had a great deal to do in connexion with our publications. There is also Dr K. E. W. Ridler, who has been with us for the past three years, but who was unable to accept a renomination. Then, unfortunately, just as we thought

we had got an honorary secretary who was going to be with us for some time and be a great help to us all, W. M. Catchpole was forced to leave us after a year's service, but we all appreciate immensely what he has done for us during that year. F. L. Garton has also retired. He has been a member of the Council since 1949, chairman of the Standardization Committee, and a great helper in our affairs; and, as we have already mentioned, D. H. Tullis, the ex-officio member for the Branches, has been replaced.

So thank you for all your help and support. I hope that you will go on preaching the usefulness of the Institute, and perhaps inducing people to present papers. The Papers Sub-Committee have quite a lot of trouble in preparing an interesting programme and one which serves a very useful purpose in the industry.

The President then delivered his Presidential Address, "Petroleum People—Planning for To-morrow," which follows on pages 252–258.

PETROLEUM PEOPLE—PLANNING FOR TO-MORROW

By C. M. VIGNOLES, C.B.E. (President)

EVER since that first well was bored—nearly 101 years ago—the oil industry has been in a constant state of change. Many of us here who have grown up—in some cases, even grown old—in the industry, naturally accept this state of affairs as normal, necessary, and desirable. I am inclined to think that we do not realize how our industry, in this respect, differs from some others; for in recent years we have all seen something of the way in which industries, unaccustomed to change for many years, go through truly " agonizing reappraisals " in their ways of life when faced with technological advances.

One result of the hurly-burly in which we live in the oil industry is that we are given few opportunities of stepping aside to see ourselves as we really are, to look at ourselves from the outside. On the other hand, change stimulates thought, and we might be less inclined to indulge in this rewarding kind of thinking if we had more time and opportunity to do it.

Such an opportunity arises in the preparation of this paper, and I propose for a few minutes to take a look at the people in the industry, our attitude to them, and, in particular, our plans for the future. They are, in a sense, a raw material, but a raw material more valuable than petroleum itself.

Rising Standards

We are all to-day much more fully alive than in the past to the factors influencing the development of our industry, amongst which not least important is our constantly expanding market. We realize that the major reason for this is the steady rise in population and in standards of living both in Britain and all over the world. We have learned, through experience, of the delicate balance that exists in a world of expanding trade—of the way in which, for instance, a period of successful and increasing exports can be followed by a sudden and commanding increase in imports. We know all about the wages and prices chase, and the importance of that ugly word " productivity," which had, I feel sure, not been invented when many of us were at school. Or, if it had been invented, it was used only by academic economists.

One such has stated that when he was a student his professors, when they wanted to illustrate the wages–prices spiral, had to go to the reign of Elizabeth I for a telling example. They do not have to delve into history to-day.

Rising standards, as we now all know, are only possible when industrial production increases more quickly than population. This has been happening, both here and in the world at large, and the result has been greatly increased demands for energy—they are now double what they were in 1938. In all this vigorous development the oil industry holds a key position: increasing markets depend on increasing population and increasing standards; these in turn depend on increasing supplies of energy, which would not have been available without our contribution.

The People

Whatever economic forces are at work, an industry, and indeed a business, will achieve a commanding position only if the leaders of the industry first put it in that position and then keep it there.

The characteristic early leaders of our industry—like the early leaders of most industries—were of the pioneer type. They were men of Napoleonic energy and achievements, who built up spectacular businesses, achieved sweeping and bold successes, and made themselves into sizeable public figures in the process. These titanic figures have passed from the scene, and the reason for this is that the industry has outgrown them.

It would be absurd and impertinent to deny these great men their tremendous success; but it would be equally absurd to suggest that we require leaders of the same type to-day.

Higher management now is staffed by men of energy and experience who have proved themselves in the most testing school of all—by competition and comparison with the fellow members of their own generations. As well as exercising formidable powers of decision and action in their own spheres, our leaders to-day are able to accept and welcome the discipline of collective responsibility when the occasion demands it, to recognize the force of collective opinion, and to acknowledge the demands of collective decisions.

To-day's leaders, we recognize, differ then in many respects from their predecessors, and rightly so. Theirs is a more complex and more demanding job, which needs different qualities. I am sure that nobody will disagree with me if I suggest that, for the next generation and those that come after, the job is going to become more complex and more demanding. The armed services are sometimes accused of busying

themselves in peace-time preparing for the last war. We should be certain that we are not, in the oil industry, doing the same thing with our human material. It would obviously be ludicrous to indulge in the training of tycoons—they are already out of date—but in the light of the unknown problems of the future, so might our present leaders be when the time came. So that a major task of to-day's management is the preparation of successors who will be able to deal with these greater but unknown management problems of the future.

The Requirement

This is the task, and it is naturally necessary to define the need rather more specifically. Leaders of men will always be found in the same way: their force of character, their knowledge of their jobs, their understanding of other people's jobs, and their capacity for hard work and sustained thought will impel them towards the top. Future leaders of ours must conform (as do our present ones) to this specification, only more so.

We can say, therefore, that we must look, first of all, for an improved general education; we must seek to improve the standards of competence in individual tasks; and seek to promote a more highly developed grasp of responsibilities.

These things are not all within the industry's own competence. But we are only entitled to ask for the co-operation of such other bodies as are affected by these problems if we first of all define our needs and then make them known in the right places.

Improved General Education

When we start to define our needs in an improved general education the first thing to do is to get over our surprise that we should be doing anything of the kind.

In recent years we have become aware of and used to the notion that industry and universities should become closely identified. Recent achievements have emphasized the growing understanding of the truth that industry and education are interdependent. The support given by industry to the foundation of new colleges at Oxford and Cambridge, both of which will have special emphasis on science graduates, is only one outstanding example of many that could be cited. The money provided by industry for such ventures is not to be regarded purely as a charitable donation. It is, far more, an investment; an investment in that most valuable raw material of all—human beings.

In recent years this sort of investment has been extended to schools. I am thinking of the fund which has been established for assisting science teaching in public and grammar schools, of bursaries, and the like.

Before I go on to suggest what more should be done, let us consider the dangers which could arise from influence over universities and schools from outside sources. This is a matter of some importance. It is right that we should suggest to educational authorities what our needs are, but it would be quite wrong for us to say how these needs should be met. In Britain a markedly sensible system has been devised whereby the Government can bring financial aid to universities without bringing undue influence to bear on how the money should be spent—the University Grants Committee. If industry is to become more intimately associated with universities and schools, then industry has got to be similarly circumspect. The essence of education lies in the development of the ability to think. Vocational training does not aspire, in itself, to do this, and if industry were to influence universities and schools unduly, they could become merely vocational training establishments for industry. This would be a national disaster, besides defeating industry's own objects.

With this proviso in mind, I shall now go on to consider what we shall require of general education in the future. I propose to consider all levels of education for two reasons: as is the case to-day, our future leaders will not be drawn from any single educational background; and, moreover, leadership is a matter which is not confined to top management.

It is frequently remarked nowadays that "standards are not what they were." In the case of human standards this is often because like is not being compared with like. People of high intelligence, who used to spend their working lives in middling jobs because they were denied educational opportunities in their youth, now pass through grammar schools, universities, or colleges of advanced technology to management jobs, the professions, and so on. In days gone by, for instance, the banks used to skim the cream of the local grammar schools annually and never had to advertise for recruits; they have to work hard to get the people they want to-day. There has been a great increase both in the numbers and the overall proportion of skilled and professional jobs. Thus the boy who to-day becomes, let us say, a policeman, is almost certainly not the same sort of boy who became a policeman 30 years ago, at any rate as far as education standards go. The recently-announced police "Sandhurst" recognizes this.

There has been, therefore, a general movement whereby talent has been lifted to a higher level of employment than it formerly occupied. Added to this, it is also the case that a great many jobs now require a higher level of attainment than before—as, for instance, to take a case with which most of us are painfully familiar, with motor mechanics. If you open the bonnet of a 1930 motor-car and do the same (if you can!) with one of this year's motor-cars, you will note at once that there is far more inside the later model. There is more to look after, more knowledge

to be acquired, additional skills to be mastered, if this same job is to be efficiently done.

We cannot doubt that these trends will continue; skilled and professional jobs will go on proliferating, and all jobs will get more complicated.

These twin tendencies can only be met in one way—by a general and overall raising of educational standards. The Crowther Report has shown that there is still an untapped reservoir of talent, and we may be certain that its suggested raising of the school leaving age is in the national, as well as the individual's, interest.

Let us turn now to the next two educational levels from which entrants to industry are now drawn and will continue to be drawn, the sixth forms of grammar and public schools, and universities. I will consider these together because what I want to say applies equally to both.

We have all of us met inarticulate specialists—men profoundly skilled in their own expertise who are unable, equally, to talk about anything else, or to make themselves understood by anyone except their brother specialists. It is a regrettable fashion, among some academic specialists, to despise the articulate man, to scorn him as a popularizer. In a world in which sciences get ever more complicated, this is profoundly depressing. It is vital that as time goes on we should have more scientists, and not fewer, who can explain to others what they are doing in their own field, and why.

This is the reason why I say that industry does not want too much specialization, especially in schools, but also in universities. Leaders of men have often, of course, started life as specialists in a particular field, but it is not their specialist training which has made them leaders of men. This is principally a matter of character, of personality traits, not of knowledge. What we require of a general education, then, is as much character-building as possible; I believe this is derived more from a broad than from a narrow education.

And here, perhaps, I may say a word about purely character-developing courses, such as those run by the Outward Bound Trust. I am sure these are tremendously valuable and that industry will go on supporting such ventures. In our present-day society of social security, especially with the ending of national service, this sort of course will be increasingly useful—overcoming unusual and unforeseen obstacles will help boys and young men to find in themselves strength of character of which they may not otherwise have been aware.

How much should industry do to help in general education? The answer must be as much as it can afford, and it cannot afford in the long run to do less than a lot. Apart from financial assistance, industry should do more than it has and is doing to make young men and boys aware of what industry has to offer in the way of a career. This is already going on, of course, to a great extent in universities; the same thing should be happening in schools.

I need not here emphasize the obvious pitfall, into which I do not believe the oil companies would fall, that headmasters and education authorities are rightly dubious about approaches to schools by industry which are in any way connected with advertising of products. Obviously our aim should be to provide information only, but in such a way that boys grow into a knowledge of industry as part of their life, not as something they find out in their last term in an interview with a careers master.

Competence in Tasks

I have suggested that all jobs, at all levels, will become more demanding in the future. I have noted that a higher general level of education will be the essential basis of the national ability to cope with this trend. And, starting from the premise that a higher general level of education exists, I want now to deal with the various specialist functions and how the demands of the future may be met there.

There has been, in recent years, a heartening increase of interest in technical education in which the Government has played a leading part. This is a subject where, quite clearly, industry and education authorities must work closely together if anything effective is to be done, and this has certainly been the case.

The Crowther Report, to which I have already referred, makes the point that no boy should be expected to pursue a course of further education only by evening classes. The report has shown that it is a wasteful system and, as many of us know, it is an extremely gruelling one. As standards go on rising in the way I have earlier suggested, these two facts will become more pronounced—the system will become more wasteful and more gruelling. There can be no doubt that the most effective systems of further education for craftsmen and technicians are block-release and day-release schemes. And of these two the block-release scheme is surely the more satisfactory, the less wasteful, and gives the boy concerned the better chance of pursuing that period of sustained endeavour and application which is necessary for the passing of any examinations.

This is not a matter for industry alone, and it provides yet another example of a joint effort with industry on the one hand and, in this case, the heads of technical schools and colleges on the other, so that each becomes more closely acquainted with the other's problems and needs. I am certain, though, that each will find the block-release system the more effective.

At present the proportion of students who are released by their employers for these and other part-time further education courses is not high, one-third

for boys and less than one-tenth for girls. Furthermore, the proportion in different industries varies tremendously. Some of the highest figures are shown, incidentally, by the coal-mining, gas, and electricity industries. I believe our own industry could do more in this respect, both on the refining and on the distributive sides, and it is certainly something to which serious attention should be directed. In the oil industry we must make the most of any potential talent, and should seek to give as many of our young people as possible such opportunities for its development as can be got. Where opportunities do not exist it is up to us to make the need known—education authorities cannot be blamed unless we do this.

When we turn from the training of craftsmen and technicians to the training of technologists we are again in a field where industry and education must continue to work jointly.

Technologists nowadays emerge from the chrysalis in one of two ways—either by pursuing full-time or sandwich courses. I am in no doubt myself that, generally speaking, sandwich courses are better, both for the young men themselves and for their employers. Technological training is essentially vocational, and rightly so. As far as we are concerned, as employers, it cannot be too vocational. It seems to me that sandwich courses offer the most satisfactory way of ensuring that qualified technologists have not only a sound academic training but also have first-hand practical knowledge of the sort of problems they are apt to come up against in their working life.

There is also this to be said: a period of training of this kind is, for the individual concerned, essentially a period of transition. It is a formative period in which school is left behind and work begins. The young man has to grow up and mature in two entirely different environments, and it is most valuable for these twin processes to alternate one with the other during training: each process can, and does, contribute much and add point to the other.

It remains a matter for regret that there are still too few qualification opportunities for technologists specifically relating to petroleum technology, and still not enough support for those that do exist. Here again the industry could do more, and I believe it could well lend its support to a national College of Petroleum Technology. Such a college has been successfully started for the aircraft industry in Britain. Colleges of petroleum technology exist in France and, you will not be surprised to hear, in Russia. We do not lack for knowledge and technical know-how, and it would surely be to our advantage, as an industry, to have an institution of this kind directly related to our own needs. I believe this is not a new idea in certain quarters, and that plans in this direction may well be maturing. Such a college could not only acquire an international reputation but would also be part of the leadership function of Britain in training candidates from Commonwealth and other overseas territories.

To turn now from technological training to formal commercial education is to turn from a thriving business to one which scarcely exists at all. In 1959 out of over 15,000 entrants for Higher National Certificates and Diplomas in England and Wales, only ten sat for the Certificate of Commerce. This is an astonishing figure to set alongside over 6600 who sat for the Certificate in Mechanical Engineering. The Minister of Education's recent re-arrangements in this field are thoroughly sensible and to be warmly welcomed.

But the plain fact remains that this branch of further education, like all the other branches, is allied very closely to the needs of business and industry. Apart from those in evening classes, all who undergo a course of further education do so for one of two reasons —either they wish to achieve a particular diploma or certificate so that they can get a particular kind of job for which that certificate is a necessary qualification or they are taking the course as part of an arrangement with their employer—one-day-a-week training, for instance, may be one of the conditions of an apprenticeship.

We can be certain that it is indeed a fact that formal commercial education is regarded by many employers with scepticism and suspicion. Most of the industrial leaders of to-day learned on the job. Can we be certain that, in the future, this is really the best method?

This is plainly a matter for industry to adjust; if industry, and business and commerce, make commercial training worthwhile, they will find plenty of young people willing to learn.

From here it is only a step to the most important training of all, training for management, and the disciplines that go with it.

This has become a very big subject in recent years. There is a great variety in the type of management training that can be got, as there is in the type of institution which provides it—universities, colleges of technology and commerce, industrial staff colleges, and so on, as well as innumerable training systems within businesses.

It is a subject to which university authorities have been giving increasing attention. Degree courses in business administration have been advocated, as has the inclusion of management studies as an essential part of third-year studies in ordinary degree courses. It is also a subject that has interested the Government for many years now. Current moves for a new diploma in management studies at post-graduate level are the latest evidence of this.

The present time, when new colleges and indeed new universities are being planned and built, is an excellent moment for consideration of these matters by authorities at all universities.

X

The present danger lies in the possibility of dangerous forms of "keeping up with the industrial Joneses." I am sure that all the courses which now exist play a part in management development. But they can do so fully only if the right man is sent on the right course at the right stage in his development; and also, of course, if the right men—the best men—are giving the instruction.

This leads me to my next thought. Let us suppose that the various suggestions I have made have all come to fruition, that is to say that the general level of education is higher; that craftsmen, technicians, technologists are all more highly qualified than to-day, and are qualified in ways directly related to the industry's needs; and that there are numerous other entrants into the industry, including graduates with commercial qualifications.

The managers will, as I have already said, not be drawn from any one of these sections: but they will, starting in whatever section as more highly qualified men, have to finish as more expert managers than to-day.

There will continue to be numerous roads to the top, as there will continue to be numerous starting points. At some point or other, perhaps several points, a business or management course may be just what is wanted to stimulate awareness, to excite interest, to develop latent talents. But these courses must be used very carefully if men, and therefore their employers, are to get the best out of them.

The career itself will remain, as it is to-day, the best training of all. What will perhaps be different from to-day is that careers will have to be planned, and planned even more carefully than hitherto.

Many valuable tools are available to managements to-day in what always has been, and will always remain, their most demanding and their most vital task: the judicious selection of subordinates. But these tools are only tools; they can never be substitutes for clear thinking on this topic, and it has never been more important than now that the right decisions are made on these matters.

Dealing with people can never, if it is to be successful, be reduced to a matter of statistics, or forms, or committees. These are only aids to man management. Integrity, genuine kindliness, sincerity, leadership, and understanding are still the fundamental basis of human relations.

Responsibility

This subject, you will recall, was one of the three I mentioned in the list of the three parts of our requirement. A higher degree of education, if it is true education, must necessarily engender in the individual a greater understanding of what the responsibilities are that are demanded of him, and a greater awareness of new responsibilities as they arise.

To illustrate this I would like to discuss four different kinds of relations—public relations, industrial relations, government relations, and race relations. I want to suggest ways in which we have become aware of our responsibilities in these matters, and to suggest how we should expect developments to arise in time to come.

Public relations did not exist in the old days, and it would be a safe guess to assume that the Napoleonic figures mentioned earlier would certainly have recoiled at the very idea—although Napoleon himself was an expert in the subject. An efficient public relations organization is now, of course, an integral part of all companies in the industry. We recognize that the public has the right to know what is going on, and that there is a duty on industry to provide reasonable information about itself.

In time to come, we may be certain, the public will become more demanding in this respect. But public relations is something more than the issuing of information in response to enquiries. It is the projection of the character of the company not merely as an honest and technically-efficient business, but as a good employer and a good citizen. The French have a magazine dealing with public relations with the title *La Maison de Verre*. There is a lot in this conception. A big company to-day is rather like a person living in a glasshouse. Its behaviour must not only be impeccable but it must also be seen to be impeccable. Leaders of industry, at all levels, will have to develop, where it does not already exist, a genuine understanding of the requirements of good public relations.

Industrial relations have always existed in this industry as in any other. But we are now a very long way from the "hiring and firing" approach to the subject. A job in the oil industry, we may now feel with pride, is a secure job, a rewarding job, in every way, and one which compares favourably *vis-à-vis* similar jobs in other industries.

The future leaders of the industry must never assume that this will always remain so. They must continuously look to other industries which are developing fast to ensure that the oil industry remains in the forefront of good industrial relations practice. The approach to this subject should always be a critical one.

The essence of good industrial relations, in my view, is that nothing should be done in the spirit I have already mentioned of keeping up with the industrial Joneses. Steps should be taken because they are desirable from the point of view of the individual, and because they are right in human terms Human attitudes are mostly deep-rooted, and consequently very difficult to change. The maintenance of good industrial relations therefore demands, above all things, extreme patience and long-term planning.

Efficient communication is another essential ingredient of successful industrial relations. We re-

cognize to-day that it is not enough to have sound reasons for a change in policy; those reasons must be clearly put before all whom the change will affect, and this must be done in good time. In this way confidence is developed within an organization, and mutual confidence is, as we all know, the essence of good teamwork.

When we turn to governmental relations we are again aware of great changes. In the earliest days, when the products we deal with played little part in the economy or lives of the people, relations between the industry, or companies, and governments were of little account. This naturally started to change before the first world war, and we live now in days when relations between some governments and some companies are of paramount and over-riding importance to both.

Things have altered so much, even in recent years, that we can now see that the industry, if it is to give of its best, should always seek to anticipate a government's attitudes and policies so as to avoid being on the defensive in any situation.

Because of the size and scope of its operations, as well as the essential nature of its products, the industry must always endeavour to co-operate, as indeed it does in most cases, with the government of the day. In countries which are primarily oil producers, lack of liaison and understanding can have disastrous results, threefold in nature—to companies operating there, to whatever government is in power, and to the economy of that country. In other countries, primarily consumers, it is no less important for marketing companies to co-operate fully with governments. As our products become increasingly important in the life of the community we can expect governments here, as elsewhere, to take an increasing interest in their impact on social and economic conditions.

When I say that we should seek to anticipate governmental attitudes and policies I do not mean to imply that we should adopt a placatory tone. The point I am making is that by recognizing clearly what these attitudes and policies are, and are likely to be, we can in good time take the necessary steps to put the facts to the people who should know them. If these things are left too late the industry, or it may be only one company, will find itself on the defensive. Decisions will be taken all too often from an emotion rather than the facts, and we must recognize that, both from our size and from our universal necessity, we are often a very vulnerable target for an emotional attack.

Future " petroleum people " will have to cultivate, wherever they are, a sensitiveness to political thinking and a keen understanding of political possibilities.

When we turn to race relations we can see at once that this is a subject in which, first of all, we have a particular interest in view of the international and world-wide character of the oil industry. We can also see that race relations have in many cases an important bearing on the three other kinds of relations I have mentioned.

In general terms there has been a revolution in attitudes to staffing the executive ranks of overseas local companies. Whereas twenty or thirty years ago these were staffed mainly by expatriates, there has been, owing to the post-war wave of nationalist sentiment, a move to introduce more and more local nationals into the firms operating in overseas territories.

We have now reached a stage when the most talented of these men must be brought into the fullest association with the company for whom they work. They must be trained, not only for management status in their own country but also, where possible, for service elsewhere.

In other words, an international industry must seek to develop a truly international system of management direction. Where there was once a wholly expatriate management team and there is now pressure for this to become a team comprised wholly of local nationals, it may not be in the best interests either of the local company or of the country in which it operates that this should happen. Better that there should be an extensive system of international cross-postings, to give those concerned the necessary experience to enable them to compete in the practice of management techniques which will, as I hope I have already shown, grow ever more complex and demanding.

General Aim for All

In the future I have been speaking about, and with the sort of changes I have foreseen, there is one vital danger which I want to mention. In a world of better-educated and more highly-qualified people there is a risk that the educational standards will come to mean more than they should. In our own time it is unthinkable that we should, for instance, employ anyone except a qualified architect to design a new building of any kind, or use anyone but a qualified doctor, or dentist, or engineer, or surveyor, and so on. Professions are, historically speaking, relatively new inventions and we live in an age of " creeping professionalism." There are more now than twenty years ago; there will be still more in ten years' time.

The danger, as I see it, is that the qualifications may come to mean more than the man; that they will be used as a kind of insurance and will no longer be a means to an end.

This danger will be, I suggest, of particular significance in Britain. The old absurd pride in the ability to " muddle through " has almost gone, and is being replaced by a healthy respect for efficiency. But other and more endearing characteristics of our race are going too—eccentrics are beginning to be regarded with something approaching suspicion; independence

of thought does not any longer command the respect it once did.

It is quite possible that we shall, unless we are careful, become as a nation the sort of people to whom the label means more than the contents, the trappings of a job more than the job itself, the public face more than the private character. I do not say that other nations do not run this risk as well; I am only certain that, at this stage in our development, we do.

In the oil industry we are fortunate to be international in character, fortunate to be involved in constant change. These circumstances keep us vital, recharge our batteries, and engender in us the healthy stimulus that stems from self-examination.

Our leaders of the future, at all levels, will profit from these twin influences. They will have to be " whole men "—men of character as well as of ability, men of purpose as well as of integrity. Compared with to-day, they will have an increasingly difficult, increasingly demanding, and increasingly complex job. But equally, it will be even more fascinating, even more rewarding, and even more dynamic than it is now. We can wish them well with fervour, with enthusiasm, and with confidence.

THE EFFECT OF ADDITIVES ON THE WATER-INDUCED PITTING OF BALL BEARINGS*

By L. GRUNBERG (Fellow)† and D. SCOTT†

SUMMARY

Using the four-ball rolling test the effect of additives in mineral oils on the water-accelerated pitting failure of ball bearings was investigated. The most effective additive found was "*iso*-amyl alcohol" (commercial secondary amyl alcohol). An imidazoline derivative used commercially as a "de-watering" agent was also effective. Surface-active agents such as oleic acid and triethanolamine were satisfactory under conditions of high supersaturation with water. Water soluble anti-corrosive and detergent additives had no beneficial action. The mechanism of "adsorption fatigue" suggested by Rebinder seemed to apply in the presence of surface-active agents.

INTRODUCTION

RECENT work [1] has shown that the presence of water in mineral oil lubricants can accelerate the pitting failure of ball bearings manufactured from conventional E.N.31 steel. Even the small quantities of water which lubricating oils are capable of dissolving are detrimental, since their removal causes an appreciable increase in the time before pit formation occurred in rolling contact.

It seemed important to search for additives which could increase the tolerance of lubricants for water, *i.e.* counteract the tendency to accelerate pitting failure in these circumstances. In order to be able to make an appropriate choice of additives, a working hypothesis about the effect of water on pitting was required, but unfortunately the whole phenomenon of the pitting failure of ball bearings is yet incompletely understood, and several hypotheses had to be considered. The presence of some additives changed the viscosity of the lubricant, and since this factor had previously been found of importance,[2,3] this problem had to be re-examined, in order to disentangle the consequences of changes in viscosity from those due to other actions of additives.

PITTING AND METAL FATIGUE

The pitting failure of ball bearings can generally be regarded as being due to the repeated stressing of a surface layer, and hence as a surface fatigue phenomenon. A certain degree of similarity between pitting and ordinary metal fatigue can therefore be expected. Comparing the two failure phenomena, one finds that in both instances the first manifestation is the appearance of cracks. In the case of metal fatigue, failure occurs through fracture, which is quite analogous to the breaking away of part of the surface when a pit is formed on the surface of a ball bearing or of a gear. Environment has been known for some time to play an important part in determining the fatigue strength, and since the surface/volume ratio of the amount of metal stressed is very much greater in pitting when only the surface layer is involved, this factor will be of even greater importance in pit formation than in ordinary fatigue failure.

It is known that a corrosive environment can greatly affect fatigue behaviour, and this subject has recently been reviewed in detail.[4] Rebinder [5] has demonstrated that whilst the fatigue endurance limit of steels may be more than halved in water as compared with that in air or in a hydrocarbon oil, the presence of *iso*-amyl alcohol in water diminished this effect somewhat. Rebinder (*loc. cit.*) distinguished between corrosion and adsorption fatigue. In the former, corrosive attack occurs, whilst in the latter, molecules of active compounds are adsorbed on the metal surface. Surface-active materials, such as oleic acid, when dissolved in inert media such as hydrocarbon oils, lower the fatigue strength to a small extent. Rebinder suggested that changes in surface energy through adsorption were responsible for this behaviour, but this cannot be regarded as a satisfactory explanation.

Some of the observations in the study of metal fatigue have their parallel in experiments on the life of ball bearings. Unpublished results obtained in the National Engineering Laboratory have shown that polyethylene-glycols can tolerate a high water content and yet give reasonable pitting life, particularly at a concentration of between 30 to 35 per cent water. Also, emulsion type lubricants, which one would expect to contain "surface-active" additives, performed well in pitting tests in spite of their high water content. Evidence is further available [6] that a "surface-active" additive (0·4 per cent amine) in a lubricating oil could prevent the corrosion of roller bearings when run under high moisture conditions.

* MS received 11 March 1960.

† National Engineering Laboratory, Thorntonhall, Glasgow.

It was suggested that this additive maintained an oil film on the metal surface, and thus prevented the occurrence of corrosion.

In view of the above, the additives which it seemed worth investigating fell broadly within the following classes:

(1) aliphatic alcohols, which by an unknown mechanism affected metal fatigue, ascribed by Rebinder to adsorptive effects;

(2) fatty acids, amines, commercial "de-watering" agents, which could be expected to form monolayers on metal surfaces;

(3) detergents, such as sodium dodecane sulphonates, which could act as emulsifiers;

(4) water soluble anti-corrosion inhibitors.

Representatives of these classes of additives were investigated in the present work.

APPARATUS AND METHOD OF TEST

The four-ball rolling test developed in the National Engineering Laboratory for determining the tendency

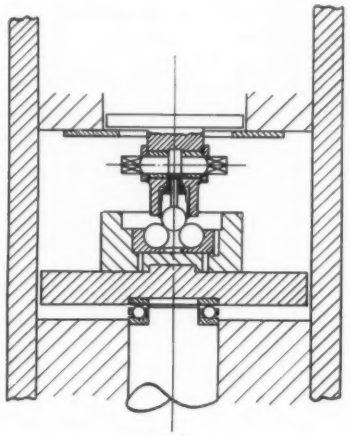


FIG 1

of lubricants to cause pitting failure was used in this investigation.[7] A modified four-ball lubricant testing machine is used in which the three lower balls are allowed to rotate in a lower race to simulate the combination of rolling and sliding experienced in an angular contact ball bearing (Fig 1). The time which elapses between the start of the test and the first appearance of a pit in the bearing surface of the top driving ball under a standard load is determined.

Four new E.N.31 steel balls were used in each test with bath lubrication. 16 ml of the lubricant to be tested, sufficient to totally immerse the balls, were used in each test. All tests were carried out under axial load of 600 kg (nominal max Hertz. stress about 500 tons/sq in) and at a speed of 1500 rev/min. After the test the damaged balls were examined by optical and electron microscopy.

MATERIALS TESTED

Two pure mineral oils generally in use in the National Engineering Laboratory were used as base oils for the additives, and are described in Table I.

TABLE I

Code letter	Type	Viscosity,* cS at 25° C	Viscosity,* cS at 50° C	Viscosity,* cS at 60° C
A	NEL reference oil 1/2/6/2. A blend of two high viscosity index components from a Venezuelan source	636	134	82
B	NEL reference oil 2/2/4/2. Distillate from a Venezuelan source	14·4	6·5	5·1

* By IP Method 71/58, "Standard Methods for Testing Petroleum and Its Products," Eighteenth Edition, Feb 1959.

The following additives were added to the base oil in the proportions indicated:

(*a*) Secondary amyl alcohol (commercial *iso*-amyl alcohol), 3 per cent.

(*b*1) Oleic acid, 2 per cent.

(*b*2) Triethanolamine, 2 per cent.

(*b*3) Commercial "de-watering" agents.

(*b*3.1) Imidazoline derivative, 2 per cent.

(*b*3.2) Sarkosine derivative, 2 per cent.

(*b*3.3) Phenoxyacetic acid, 2 per cent.

In order to test the effect of water soluble materials, these were added in the form of aqueous solution during the test.

(*c*) Sodium dodecane sulphonate, 0·5 per cent representing detergents.

(*d*) 0·5 sodium nitrite plus 0·5 sodium benzoate, representing anti-corrosion inhibitors.

CONDITIONS OF WATER CONTAMINATION INVESTIGATED

The oils were tested under five different conditions of water content:

I. *Dry.*—The oil was dried over metallic sodium for 24 hours before test.

II. *As Received.*—Moisture content by the Karl Fischer method [8]: Oil A, 0·002 per cent; Oil B, 0·004 per cent.

III. *Saturated with Water before Test.*—A sample of oil was thoroughly shaken with an equal volume of water, then allowed to settle 24 hours. The oil was carefully decanted for the test. Moisture content: Oil A, 0·014 per cent; Oil B, 0·011 per cent.

IV. *Supersaturated with Water during Test.*—To ensure excess water during test, a small quantity ($\frac{1}{2}$ ml) was added to the lubricant bath

containing saturated oil at the start of each test. Approx water content: 3 per cent.

V. *Highly Supersaturated with Water During Test.*—As III, but adding 1 ml of water. Approx water content: 6·0 per cent.

RESULTS

(i) *Effect of Water Content of Base Oils*

The results obtained are given in Table II.

TABLE II

Lubricant A	Conditions	I	II	III	IV	V
	Mean life (minutes)	*121*	*63*	*55*	*26*	*21*
	Standard deviation	20	24	24	16	8
	Coefficient of variation, %	17	39	44	62	38
	No. of tests	5	23	14	7	8
Lubricant B	Conditions	I	II	III	IV	V
	Mean life (minutes)	*65*	*48*	*44*	*10*	*6*
	Standard deviation	15	26	24	8	4
	Coefficient of variation, %	22	54	55	80	67
	No. of tests	8	20	15	8	16

The experimental results confirm previous findings by demonstrating that the presence of water in mineral oils accelerated the pitting type failure of conventional E.N.31 steel ball bearings [1] and that the more viscous oil gave a longer time to pitting failure.[2, 3]

(ii) *Effect of Addition of Secondary Amyl Alcohol (Commercial "* iso*-Amyl Alcohol ")*

"*iso*-Amyl alcohol" was used in a concentration of 3 per cent as an additive in the two base oils and tested under conditions III and IV. Since the addition of the rather fluid alcohol was expected to affect the viscosity of the oils, this was determined at 25° and 50° C. These data and the experimental results on pitting are summarized in Table III.

TABLE III

Pitting Tests on Base Oils + 3% " iso*-Amyl Alcohol "*

Base oil A	Conditions	III	IV
	Mean life (minutes)	*93*	*33*
	Standard deviation	29	22
	Coefficient of variation, %	31	67
	No. of tests	11	14
	Viscosity, cS at 25° C	410	
	Viscosity, cS at 50° C	86·1	
Base oil B	Conditions	III	IV
	Mean life (minutes)	*50*	*34*
	Standard deviation	4	24
	Coefficient of variation, %	8	70
	No. of tests	8	17
	Viscosity, cS at 25° C	12·4	
	Viscosity, cS at 50° C	5·81	

The addition of "*iso*-amyl alcohol" partially counteracted the deleterious effects of the presence of water, and the results are therefore analogous to the findings of Rebinder [5] in ordinary fatigue tests with similar steel.

In spite of the considerable lowering of the viscosity which one would expect to be detrimental, the effect of "*iso*-amyl alcohol" is to raise the pitting life from 55 to 93 minutes and from 44 to 50 minutes under the condition of water saturation (III). Under supersaturation (IV) the increases are from 26 to 33 minutes and from 10 to 34 minutes respectively.

(iii) *Effect of Fatty Acids and Amines*

Blends of the base oils with 2 per cent each of oleic acid and triethanolamine were prepared. The results of the pitting tests and the viscosity data with the oleic acid blends are given in Table IV and those of the triethanolamine blends in Table V.

TABLE IV

Pitting Tests with 2 per cent Oleic Acid Blends

Lubricant A	Condition	III	V
	Mean life (minutes)	*33*	*32*
	Standard deviation	12	19
	Coefficient of variation, %	36	59
	No. of tests	10	9
	Viscosity, cS at 25° C	540	
	Viscosity, cS at 50° C	127	
Lubricant B	Condition	III	V
	Mean life (minutes)	*27*	*23*
	Standard deviation	14	10
	Coefficient of variation, %	52	44
	No. of tests	7	8
	Viscosity, cS at 25° C	14·5	
	Viscosity, cS at 50° C	6·63	

TABLE V

Pitting Tests with 2 per cent Triethanolamine Blends

Lubricant A	Condition	III	V
	Mean life (minutes)	*40*	*38*
	Standard deviation	19	17
	Coefficient of variation, %	47	45
	No. of tests	16	18
	Viscosity, cS at 25° C	619	
	Viscosity, cS at 50° C	124	
Lubricant B	Condition	III	V
	Mean life (minutes)	*29*	*26*
	Standard deviation	10	14
	Coefficient of variation, %	34	54
	No. of tests	9	15
	Viscosity, cS at 25° C	14·3	
	Viscosity, cS at 50° C	6·50	

Both oleic acid and triethanolamine *lowered* the pitting life when using the lubricants under conditions of water saturation (III). This finding is analogous to that of Rebinder that oleic acid lowered the fatigue strength of steels. Yet under the condition of high supersaturation (V) the pitting life is *raised* as compared with the performance of the undoped lubricants. From Tables IV and V it emerges that the pitting life was relatively *independent* of the amount of water present and solely determined by the nature of the additive.

(iv) *Additives Designed to have a "De-watering" Effect on the Surface*

Many "de-watering" agents are marketed as corrosion inhibitors. Only oil-soluble materials ap-

peared of interest for the present investigation and three, namely, an imidazoline derivative, a sarkosine derivative, and phenoxy acetic acid, were studied in concentrations of 2 per cent in base oils A and B.

The results of the pitting tests and viscosity data are given in Table VI.

TABLE VI

		2% Imidazoline derivative		2% Sarkosine derivative		2% Phenoxy acetic acid	
Lubricant A	Condition	III	V	III	V	III	V
	Mean life (minutes)	*70*	*37*		*18*		*17*
	Standard deviation	36	20		16		17
	Coefficient of variation, %	51	54		87		100
	No. of tests	13	13		7		13
	Viscosity, cS at 25° C	613		616		643	
	Viscosity, cS at 50° C	129		134		134	
Lubricant B	Condition	III	V	III	V	III	V
	Mean life (minutes)	*50*	*17*		*4*		*8*
	Standard deviation	21	9		2		4
	Coefficient of variation, %	42	53		50		50
	No. of tests	10	12		8		10
	Viscosity, cS at 25° C	15·2		15·1		15·3	
	Viscosity, cS at 50° C	7·07		6·82		6·74	

From Table VI it appears that only one additive was effective. In its action this additive (an imidazoline derivative) acted similarly, but not quite as effectively, as "*iso*-amyl alcohol." Under saturation conditions (III) it increased the pitting life by 27 (oil A) and 14 per cent (oil B), and under high supersaturation (V) it approximately doubled the pitting life with both oils A and B.

The other two additives (a sarkosine derivative and phenoxy acetic acid), although reputedly anticorrosives by the same "de-watering" action of the surface as the imidazoline derivative, had the opposite effect in decreasing somewhat the pitting life under high supersaturation. The former two additives contain carboxyl groups absent in the imidazoline derivative.

(v) *Use of Conventional Static Corrosion Inhibitors*

The effect of conventional static corrosion inhibitors was assessed by adding sodium benzoate and sodium nitrite in the proportion normally employed for anticorrosion purposes, namely, 0·5 per cent of each, relative to the total amount of fluid present in the lubricant bath. The test results are summarized in Table VII and indicate that these additives were not effective.

TABLE VII

Pitting Results in the Presence of Sodium Benzoate and Sodium Nitrite

Lubricant A	Condition	V
	Mean life (minutes)	*23*
	Standard deviation	23
	Coefficient of variation, %	100
	No. of tests	15
Lubricant B	Condition	V
	Mean life (minutes)	*7*
	Standard deviation	4
	Coefficient of variation, %	57
	No. of tests	11

(vi) *Detergent Additive*

The results obtained with a detergent type additive (0·5 per cent sodium dodecane sulphonate), summarized in Table VIII, show that this was not effective.

TABLE VIII

Pitting Results in the Presence of Sodium Dodecane Sulphonate

Lubricant A	Condition	V
	Mean life (minutes)	*20*
	Standard deviation	13
	Coefficient of variation, %	65
	No. of tests	8
Lubricant B	Condition	V
	Mean life (minutes)	*4*
	Standard deviation	1
	Coefficient of variation, %	25
	No. of tests	5

In order to facilitate the comparison of the results of the pitting tests, these are summarized in Table IX.

TABLE IX

Summary of Pitting Tests

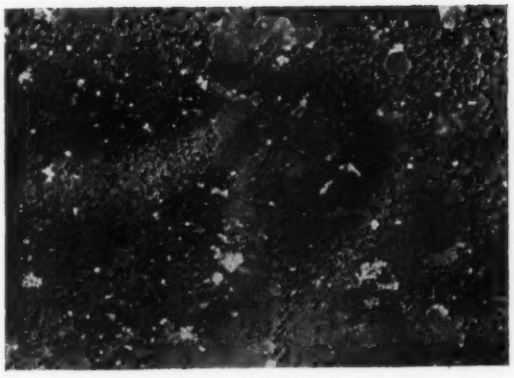
Degree of water contamination	Additive concentration	Mean life (minutes)	
		Base oil A	Base oil B
Dry (I)		121	65
As received (II)		63	48
Saturated (III)		55	44
Supersaturated (IV)		26	10
Highly supersaturated (V		21	6
Saturated (III)	3% *iso*-amyl alcohol	93	50
Supersaturated (IV)	3% *iso*-amyl alcohol	33	34
Saturated (III)	2% oleic acid	33	27
Highly supersaturated (V)	2% oleic acid	32	23
Saturated (III)	2% triethanolamine	40	29
Highly supersaturated (V)	2% triethanolamine	38	26
Saturated (III)	2% imidazoline derivative	70	50
Highly supersaturated (V)	2% imidazoline derivative	37	17
Highly supersaturated (V)	2% sarkosine derivative	18	4
Highly supersaturated (V)	2% phenoxy acetic acid	17	8
Highly supersaturated (V)	0·5% sodium benzoate and sodium nitrite	23	7
Highly supersaturated (V)	0·5% sodium dodecane sulphonate	20	4

EXAMINATION OF SPECIMENS BY ELECTRON MICROSCOPY

It was noted that the appearance of the bearing tracks on the upper balls was different with different lubricants. For instance, the bearing tracks obtained under highly supersaturated conditions (V) were stained a brownish colour, whilst the same lubricant containing a surface-active agent produced tracks which were bright and polished.

It seemed interesting to obtain detailed records of tracks by electron microscopy using shadowed formvar replicas. This technique revealed that the tracks on balls tested under highly supersaturated conditions (V) in the absence of additives were covered by fine surface pits and debris (Fig 2 (*a*) and (*b*) ×20,000).

(*a*)



(*b*)

FIG 2

× 20,000 (reduced to half-size)

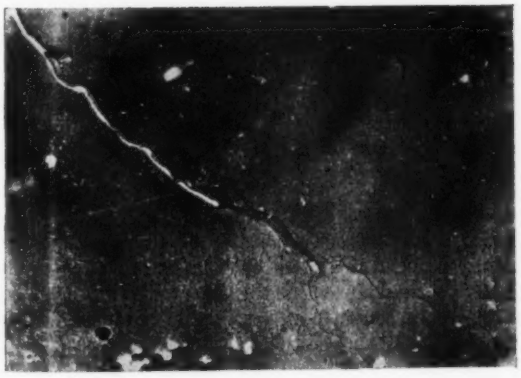


FIG 3

× 20,000 (reduced to half-size)

FIG 4

× 15,000 (reduced to half-size)

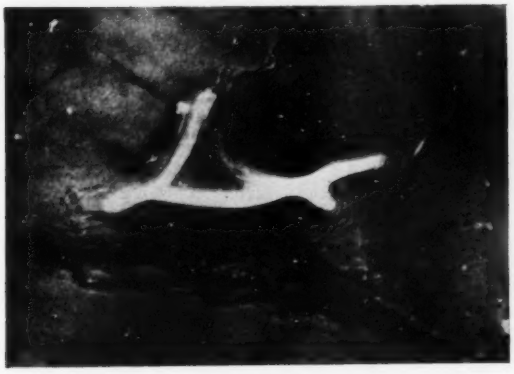


FIG 5

× 15,000 (reduced to half-size)

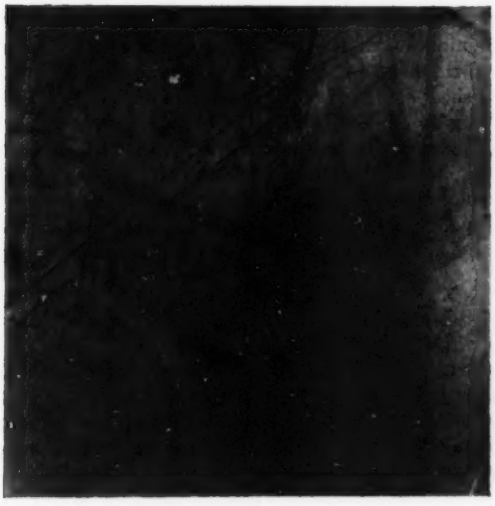


FIG 6

× 6000

The bright tracks of balls tested under the same condition in a lubricant containing oleic acid were free from this form of attack. Fig 3 (×20,000) shows the smooth polished surface of the track and the presence of a crack. Evidence of surface deformation was found on the same track (Fig 4, ×15,000) and frequently it was found that cracks were found within deformed areas (Fig 5, ×15,000).

The tracks of balls immediately after being tested under saturated condition (IV) with a lubricant containing "*iso*-amyl alcohol" were bright but

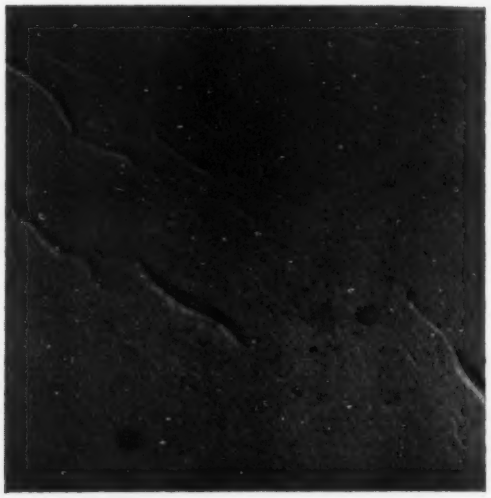
FIG 7
× 10,000

became stained on standing. Electron microscopical examination of the track immediately after test revealed that the surface was mainly smooth and polished as found with oleic acid. Fig 6 (×6000) shows an edge of track; the smooth polished nature of the track can be compared with the original surface at the top of the electron micrograph. Some areas of surface showed evidence of smoothing by plastic flow (Fig 7, ×10,000). Some surface cracks and areas of roughening were also found (Fig 8 (*a*) and (*b*) ×4000).

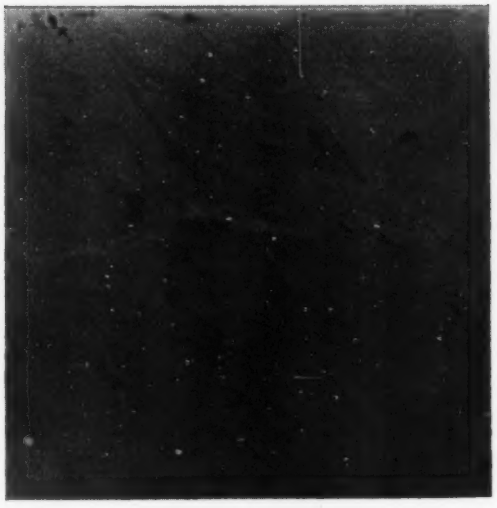
THE EFFECT OF VISCOSITY

It has previously been demonstrated [2] that with mineral oils the pitting life increased with increasing viscosity. This effect must be taken into account when considering additives, since the latter change the viscosity and hence the pitting characteristics.

A series of mineral oils derived from the same crude oil, but of different viscosities, were tested in the rolling four-ball machine. The viscosity of the oils was also determined. Fig 9 shows on a log log basis the relationship between the pitting life and the viscosity of the oil at 50° C. This temperature was



(*a*)



(*b*)
FIG 8
× 4000

chosen, since it corresponded to the temperature usually reached in the oil bath during a test. From Fig 9 one can deduce that the slope of the straight line is approximately 0·3, in reasonable agreement with the value of 0·2 suggested by Carter.[3]

Thus for mineral oils generally $\frac{\tau_1}{\tau_2} \sim \left(\frac{\gamma_1}{\gamma_2}\right)^{0\cdot3}$, where τ is the pitting life and γ the kinematic viscosity

at 50° C of oils 1 and 2 respectively. Although this relationship may not hold fully for blends of mineral oils with materials of other chemical composition, it is probably sufficiently applicable to enable segregation of the effect of viscosity from that from other causes.

Taking, for instance, the blends containing 3 per cent "*iso*-amyl alcohol," if the additive would have no other effect than lowering the viscosity, then under

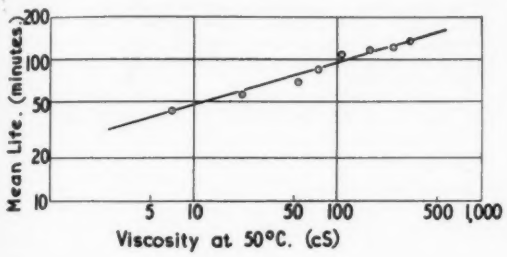


FIG 9

condition (III) τ would have been *reduced* for oil A by a factor of $(86{\cdot}1/134)^{0{\cdot}3}$, *i.e.* 0·876, to give $\tau_{\text{Blend III}}$, = 48·2 minutes instead of 93 minutes as observed. The *improvement* produced by the additive corresponds to a factor of 93/48·2 = 1·93, only slightly lower than the improvement factor 121/55 = 2·22 obtained when oil A is completely dried (I) from the fully saturated condition (III). For oil B the viscosity factor is $(5{\cdot}81/6{\cdot}5)^{0{\cdot}3} = 0{\cdot}966$ and the calculated $\tau_{\text{Blend III}}$, = 42·6 minutes, as against the observed value of 50 minutes. The improvement factor (50/42·6) is 1·175, which is less than the improvement factor of (65/44) = 1·478 obtained by drying the oil from condition III to I.

The general conclusion which can be derived from these calculations is that the effect of useful additives is more spectacular the higher the viscosity of the base oil. The same applies, of course, to the beneficial effect of complete removal of traces of water from oils.

DISCUSSION

Several important conclusions can be derived from the experiments. The highly detrimental effect of water contamination on the pitting failure of ball bearings can be counteracted by the addition to mineral oils of "*iso*-amyl alcohol." In some instances this additive increased the life of mineral oils saturated with water almost as much as the complete removal of water from the oil by treatment with metallic sodium. "*iso*-Amyl alcohol" also increased the pitting time under supersaturated conditions, when free and undissolved water was present. A commercial "de-watering" agent (an imidazoline derivative) acted in a similar way. In contrast with this, so-called "surface-active" additives, such as oleic acid and triethanolamine, behaved quite differently. In the absence of free and undissolved water and under conditions of supersaturation, these additives gave pitting times which were almost identical. From these observations it is possible to deduce tentatively that "*iso*-amyl alcohol" and the imidazoline derivative prevented action by the water dissolved in the oil, namely, they were acting within the lubricant phase, whilst oleic acid and triethanolamine produced an adsorbed monolayer on the surface of the balls, giving pitting times independent of the degree of water contamination. Only oleic acid and triethanolamine could be regarded as acting in the sense of Rebinder's "adsorption fatigue," whilst other mechanisms may be important with "*iso*-amyl alcohol" and the imidazoline derivative. "Corrosion-fatigue" plays some part in pitting but is not inhibited by water-soluble anti-corrosives and "de-watering" agents other than the imidazoline derivative.

At this stage it seems permissible to speculate on the basis of the yet meagre experimental data about a possible mechanism by which the water-accelerated pitting failure occurred and the action of additives on this process. The hypothesis which can be put forward is that straining of the surface layer produced a high concentration of vacancies in the metal, and if a ready source of hydrogen ions or atoms were available vacancy-induced diffusion of hydrogen into the surface would occur. The increase in hydrogen concentration in the surface would produce "hydrogen embrittlement" and accelerate the formation of cracks and pits. Similar suggestions have already been made when considering the causes of fatigue failure. Morgan [9] suggested that premature failure was due to hydrogen embrittlement, and Siede and Rostoker [10] explained how hydrogen diffusion could reasonably account for flaking and fatigue failure by the stabilization of the transient and thermally generated crack nuclei formed at low stress concentrations. Petch [11] suggested that hydrogen adsorption could reduce the surface energy and thus account for the reduced stress for crack propagation. There remains to suggest a mechanism by which water in contact with a strained metal could act as a source of hydrogen ions or atoms. It is known that water and oxygen can produce hydrogen peroxide on freshly deformed surfaces, and it has been suggested that one of the intermediates of the reaction was free radicals of hydrogen, *i.e.* hydrogen atoms.[12] Such free radical surface reaction could provide the atomic hydrogen required for hydrogen embrittlement of the surface to occur. It seems likely that "surface-active" additives would greatly interfere with such reactions. A considerable amount of work is still required before these complicated phenomena could be fully explained and understood.

The practical use of alcohols for the prevention of

water-induced pitting is at present subject to a patent application.

ACKNOWLEDGMENTS

The work described has been carried out in the National Engineering Laboratory of the Department of Scientific and Industrial Research and is published by permission of the Director. The authors wish to thank H. O'Gorman, who carried out the experimental work, and Mrs H. M. Scott, who prepared the electron micrographs. The samples of imidazoline and sarkosine derivatives and of phenoxy acetic acid were provided by The Geigy Company Ltd of Manchester, and their co-operation is herewith acknowledged.

References

[1] Grunberg, L., and Scott, D. *J. Inst. Petrol.*, 1958, **44**, 406–10.
[2] Barwell, F. T., and Scott, D. *Engng, Lond.*, 1956, **182**, 9.
[3] Carter, T. L. NACA Tech. Note 4101, 1957.
[4] Gilbert, P. T. *Inst. of Metals, Metallurgical Reviews*, 1956, **1**, Pt 3, 379–417.
[5] Likhtman, V. I., Rebinder, P. A., and Karpenko, G. V. "Effect of a Surface-Active Medium on the Deformation of Metals," Moscow: USSR Academy of Sciences, 1954.
[6] Peterson, W. H., *et al. NLGI Spokesm.*, 1957, **22** (8), 18–25.
[7] Scott, D. 1957, Inst. Mech. Engrs, Proceedings of Conference on Lubrication and Wear, Paper 58, 463–8.
[8] Fischer, K. *Angew. Chem.*, 1935, **48**, 397.
[9] Morgan, P. G. *Iron & Steel*, 1958, **31**, 609.
[10] Siede, A., and Rostoker, W. *Trans. Met. Soc., AIME*, 1958, **212**, 852.
[11] Petch, N. J. *Philosophical Mag. Series* 8, 1956, **1**, 331.
[12] Grunberg, L. *Proc. Phys. Soc., Lond.*, 1953, **B LXVI**, 153.

THERMAL CONDUCTIVITY MEASUREMENTS ON OILS *

By R. W. POWELL † and A. R. CHALLONER †

SUMMARY

Measurements are described, using the guarded hot-plate apparatus, which support the thermal conductivity values previously obtained in this laboratory for oils, and which provide data for present-day transformer oils.

A recent publication had expressed doubts regarding the accuracy of thermal conductivity determinations made in apparatus of this type, but these are dispelled, and the values for transformer oil which gave rise to them are considered to be in error.

INTRODUCTION

MODERN developments have created an increased interest in the thermal conductivities of liquids. A knowledge of thermal conductivity is required in problems involving fluid flow as well as when the liquid is at rest, for thermal conductivity is one of the quantities in the dimensionless groups relating to convective heat transfer. Since the measurement of liquid thermal conductivities suffers from the possible effects of convection in addition to the usual difficulties, it is not surprising that considerable errors appear to have been associated with some published values. This was made apparent in a recent paper by the present authors,[1] which was intended to give reliable values for a few liquids. The thermal conductivities of water, heavy water, glycerol, ethyl alcohol, toluene, medicinal paraffin, and carbon tetrachloride were measured over the range 1° to 82° C in a guarded hot-plate apparatus, and the values were regarded as accurate to ±1 per cent. In some instances excellent agreement had been obtained with the results of earlier workers, often confirming that quite different experimental methods gave closely similar values. In others, however, differences of up to 50 per cent were disclosed, suggesting that serious errors had been present. For instance, there were indications that the often quoted values [2] for the thermal conductivities of liquid refrigerants of the fluorochloro derivatives of methane and ethane were much too high, and subsequent measurements have confirmed this,[3] thus supporting earlier German [4] and Russian work [5] on these liquids. No evidence had been obtained to suggest that the accuracy of our measurements was well outside the stated ±1 per cent.

At the Symposium on Thermal Properties held at Purdue University, Lafayette, Indiana, in February 1959, however, a paper was presented by Allen [6] which must have caused some concern, not only to workers on liquid thermal conductivities but also to users of data for the thermal conductivity of transformer oils.

Allen employed the line-source transient method for thermal conductivity determinations over the range 20° to 80° C for a transformer oil and obtained a large positive temperature coefficient of about 60×10^{-4} per °C, as derived from his drawn line. This result is surprising, since such fluids usually have small negative coefficients, yet Allen, without checking his method with any other liquid, proceeds to suggest that the steady state methods used by other workers might have been in error. Experimental evidence is obtained, in rather different circumstances, to show that an electrostatic potential might develop across the plates of a steady state thermal conductivity apparatus, and that this could inhibit the heat transfer to a greater extent at high than at low temperatures, and could lead to lower or even negative temperature coefficients being obtained. Allen concludes that such errors have frequently occurred and have probably masked the true variation of thermal conductivity with temperature. He recommends that an electrical connexion should be provided between the hot and cold plates.

It is, of course, well known [7] that appreciable voltages can set up convection in a liquid and thus modify the heat transfer, but it had not been considered likely that any such effect could be present during a normal thermal conductivity determination. In our own work all necessary checks had been made to ascertain that the thermocouple readings were uninfluenced by leakage from the power supplies, but the hot and cold plates had not been electrically connected as suggested.

In view of the suggestion made by Allen, check observations appeared desirable on an actual thermal conductivity apparatus of the plate type. These are described below, and show that no errors of the kind suggested were present. Finally, thermal conductivity determinations are reported for several samples of transformer oil, including one supplied by Allen. There are strong indications that his original values were subject to considerable error.

CHECK MEASUREMENTS USING MEDICINAL PARAFFIN

Whereas for transformer oil Allen had obtained a strong positive coefficient, Kaye and Higgins [8] at the National Physical Laboratory, and later Schmidt and

* MS received 17 February 1960.

† National Physical Laboratory, Teddington, Middlesex.

Leidenfrost,[7] using other forms of the plate apparatus, and Tsederberg,[9] using a hot-wire steady state method, had obtained small negative coefficients that were of comparable order. Kaye and Higgins had included five other oils in their investigation, all of which gave small negative coefficients, and this holds for other oils studied in this laboratory.[10] Medicinal paraffin was one of the oils studied by Kaye and Higgins and leads. Another pair of thermocouples, one from each plate, were then connected together, and 30 minutes or so later another set of conductivity observations was taken. The measurements were repeated after connecting the thermocouple lead attached to the hot plate directly on to the iron base plate.

In the course of further measurements at an intermediate mean temperature of 43·6° C, some observa-

TABLE I

Thermal Conductivity Determinations on Medicinal Paraffin, Made Under Various Conditions Designed to Check that Results Normally Obtained are Free from Electro-Thermal Effects

Comment	Temperature, ° C				Amps	Volts	Thermal conductivity Jcm/cm² sec, ° C
	Hot face	Cold face	Difference	Mean			
Normal conditions	$25{\cdot}87_5$	$22{\cdot}01_5$	$3{\cdot}86_0$	$23{\cdot}94_5$	0·2097	6·656	$0{\cdot}00128_1$
Normal conditions	$25{\cdot}97_3$	$22{\cdot}01_5$	$3{\cdot}95_8$	$23{\cdot}99_4$	0·2096	6·655	$0{\cdot}00125_2$
Normal conditions	$25{\cdot}96_9$	$22{\cdot}02_0$	$3{\cdot}94_9$	$23{\cdot}99_4$	0·2096	6·659	$0{\cdot}00125_6$
Measured voltage of 0·6 v across hot and cold plates	$25{\cdot}90_8$	$22{\cdot}01_5$	$3{\cdot}89_3$	$23{\cdot}96_1$	0·2095	6·653	$0{\cdot}00127_1$
Hot and cold plates connected electrically for 45 min	$25{\cdot}92_2$	$22{\cdot}02_5$	$3{\cdot}89_7$	$23{\cdot}97_3$	0·2095	6·653	$0{\cdot}00127_0$
Hot plate and base plate connected electrically	$25{\cdot}92_2$	$22{\cdot}02_0$	$3{\cdot}90_2$	$23{\cdot}97_1$	0·2095	6·653	$0{\cdot}00126_9$
Average				$23{\cdot}97_3$			$0{\cdot}00126_7$
Normal conditions (about 7 v observed between hot and cold plates)	$61{\cdot}97_3$	$58{\cdot}07_8$	$3{\cdot}89_5$	$60{\cdot}02_5$	0·2080	6·636	$0{\cdot}00125_9$
Hot and cold plates electrically connected	$61{\cdot}97_3$	$58{\cdot}07_8$	$3{\cdot}89_5$	$60{\cdot}02_5$	0·2080	6·631	$0{\cdot}00125_8$
Hot plate and base plate electrically connected	$61{\cdot}97_3$	$58{\cdot}07_8$	$3{\cdot}89_5$	$60{\cdot}02_5$	0·2078	6·625	0·00125
Average				$60{\cdot}02_5$			$0{\cdot}00125_8$
Normal conditions	$43{\cdot}59_8$	$39{\cdot}74_6$	$3{\cdot}85_2$	$41{\cdot}67_2$	0·2079	6·616	$0{\cdot}00126_8$
Normal conditions	$43{\cdot}59_0$	$39{\cdot}72_6$	$3{\cdot}86_4$	$41{\cdot}65_8$	0·2080	6·612	$0{\cdot}00126_5$
+ 27 v applied through $4{\cdot}7 \times 10^6$ ohms	$43{\cdot}59_7$	$39{\cdot}71_6$	$3{\cdot}88_1$	$41{\cdot}65_1$	0·2080	6·604	$0{\cdot}00125_9$
− 27 v applied through $4{\cdot}7 \times 10^6$ ohms	$43{\cdot}59_7$	$39{\cdot}70_9$	$3{\cdot}88_8$	$41{\cdot}65_3$	0·2083	6·603	$0{\cdot}00125_8$
Average				$41{\cdot}65_8$			$0{\cdot}00126_2$

At the three temperatures studied the average values agree with our previous determinations [1] to within 0·3 per cent.

for this oil our values [1] and those of Kaye and Higgins agreed to within 0·75 per cent over the common temperature range, 20° to 80° C. Medicinal paraffin therefore seemed a suitable liquid to use for the initial check measurements.

Measurements on medicinal paraffin of BP quality were undertaken in the guarded hot-plate apparatus previously described, but after the surfaces of the hot and cold plates had been nickel plated and re-lapped. All determinations were made using a liquid thickness of 0·3 cm. For the first set of measurements at mean temperatures of 24° and 60° C the normal procedure was unchanged. Measurement was then made of any voltage difference between the hot and cold plates, and after this had been observed for 45 minutes or so the observations for a thermal conductivity determination were repeated. In the course of these measurements two of the thermocouples were used as tions were taken after a potential of 27 v had been applied, through a resistance of $4{\cdot}7 \times 10^6$ ohms, to either the hot or the cold plate. In each instance, ample time was allowed for the effect of any consequent change in the temperature distribution to become established.

The results of these experiments are given in detail in Table I. Any thermal conductivity changes are seen to be small and are within the normal accuracy of observation, even the directly applied voltage having but little influence.

These average values are plotted in Fig 1, together with the mean line which Kaye and Higgins fitted through their experimental observations for medicinal paraffin. Here again the extreme variation is only 1 per cent.

From these results it is concluded that neither our earlier measurements on medicinal paraffin nor those

of Kaye and Higgins could have been subject to any error of the type and magnitude suggested by Allen.

CHECK MEASUREMENTS USING TRANSFORMER OIL

The apparatus was later charged with a sample of transformer oil and a somewhat similar series of tests made. The transformer oil was of a grade currently in use by the Ministry of Works. The results obtained are given in Table II.

TABLE II

Results for a Sample of Transformer Oil (Ministry of Works)

Comment	Temperature, °C				Amps	Volts	Thermal conductivity, Jcm/cm² sec ° C
	Hot face	Cold face	Difference	Mean			
Normal conditions	$27{\cdot}86_2$	$23{\cdot}26_0$	$4{\cdot}60_2$	$25{\cdot}56_1$	0·2165	6·877	$0{\cdot}00114_7$
27 v applied through $4{\cdot}7 \times 10^6$ ohms	$27{\cdot}83_1$	$23{\cdot}24_5$	$4{\cdot}58_6$	$25{\cdot}53_8$	0·2162	6·850	$0{\cdot}00141_7$
Average				$25{\cdot}5_5$			$0{\cdot}00114_7$
Hot and cold plates electrically connected	$62{\cdot}97_3$	$58{\cdot}42_3$	$4{\cdot}54_5$	$60{\cdot}70_0$	0·2161	$6{\cdot}894_5$	$0{\cdot}00116_2$
As above	$62{\cdot}97_3$	$58{\cdot}41_9$	$4{\cdot}55_4$	$60{\cdot}69_6$	0·2160	$6{\cdot}887_5$	$0{\cdot}00115_9$
+ 27 v applied through $4{\cdot}7 \times 10^6$ ohms	$62{\cdot}97_3$	$58{\cdot}41_4$	$4{\cdot}55_9$	$60{\cdot}69_3$	0·2160	$6{\cdot}883_5$	$0{\cdot}00115_7$
− 27 v applied as above	$62{\cdot}97_3$	$58{\cdot}40_9$	$4{\cdot}56_4$	$60{\cdot}69_1$	0·2159	$6{\cdot}899_5$	$0{\cdot}00115_7$
Average				$60{\cdot}69_5$			$0{\cdot}00115_9$
Apparatus emptied and refilled. Normal conditions	$27{\cdot}66_1$	$22{\cdot}80_0$	$4{\cdot}86_1$	$25{\cdot}2_3$	0·2220	$7{\cdot}055_7$	$0{\cdot}00114_3$
As above	$27{\cdot}64_1$	$22{\cdot}79_7$	$4{\cdot}84_4$	$25{\cdot}2_2$	0·2221	$7{\cdot}055_7$	$0{\cdot}00114_3$
Average				$25{\cdot}2_2$			$0{\cdot}00114_5$

Once again the applied voltage is seen to have but little influence on the thermal conductivity. The absolute values do, however, call for comment, since they are 14 per cent and 11 per cent lower than the value obtained by Kaye and Higgins at 25° and 60° C. The present values also differ in having a small positive temperature coefficient of about 3×10^{-4}, although this is still about a twentieth of Allen's coefficient. These results are also plotted in Fig 1.

Bearing in mind the good agreement shown by the present results for medicinal paraffin with those of Kaye and Higgins, it would appear that the thermal conductivity of this sample of transformer oil is considerably lower than that which was available in 1928. Changes have no doubt been made to improve other properties, and it was deemed desirable to measure the thermal conductivities of some further present-day transformer oils.

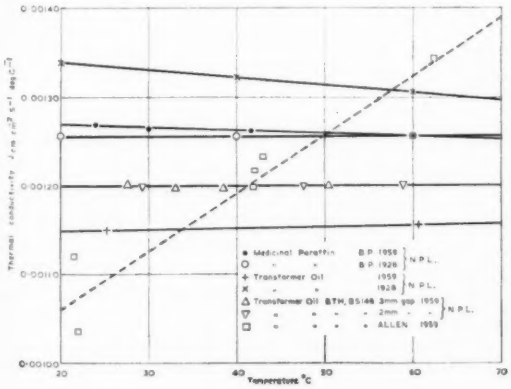


FIG 1

TEMPERATURE VARIATION OF THERMAL CONDUCTIVITY

MEASUREMENTS ON THE TRANSFORMER OIL USED BY ALLEN

At this stage of the investigation P. H. G. Allen was informed of the results being obtained, and he kindly supplied a sample of the transformer oil that he had used. This was stated by him to be an oil conforming to BS 148, and supplied by Wakefield-Dick Industrial Oils Ltd. As Allen considered this oil to be relatively transparent to radiation,* it was decided to carry out measurements with two different oil thicknesses of 0·3 and 0·2 cm. The results for these two thicknesses are plotted in Fig 1 and are seen to agree closely and to indicate a value of 0·001200 Jcm/cm² sec ° C, the

* Private communication.

The statement in ref 6 that Dick and McCready had experimentally confirmed the presence of radiation by tests on films of various thickness is not consistent with their paper. They consider the issue to be complicated by stray heat losses.

thermal conductivity being independent of temperature over the range studied.

Another check of the absence of any electro-thermal effects was made at the highest temperature (58·8° C) where thermal conductivity values obtained in the normal way and then with the hot and cold plates electrically connected only increased by 3 parts in 1200.

Allen's values are also plotted in Fig 1. They show considerably more scatter, as well as the unusually large coefficient, and it can only be concluded that these values were subject to error. The most likely cause is convection. Not necessarily convection set up by the hot wire, but convection set up by stirring, or by local temperature differences and present at the time of his experiment. Allen had a long wire immersed in a large volume of liquid. Local temperature inequalities would tend to be greater at higher temperatures, where the viscosity would be lower. Fluid movement is likely to persist for a considerable time after stirring had been switched off and to be more pronounced at the higher temperatures. Any such fluid movement would augment the heat transfer from the wire and could explain the resulting large temperature coefficient, but not the low values obtained at 22° C.

MEASUREMENTS ON THREE OTHER TRANSFORMER OILS

The three other transformer oils for which thermal conductivity determinations were later made using

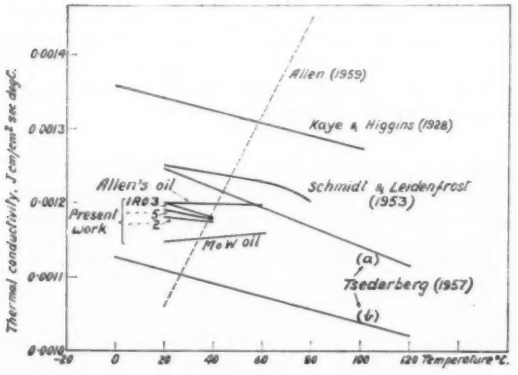


FIG 2

THERMAL CONDUCTIVITIES OF TRANSFORMER OILS

the 0·3-cm spacing between the plates were samples of oils that featured in another investigation.[11] These were referred to as Insulating Reference Oils (IRO) Nos 2, 3, and 5. The results for these oils are plotted in Fig 2. The values are all comparable with one another and show small negative temperature coefficients. The values are seen to agree to within 2 per cent with the values obtained by the authors for the oil used by Allen. Fig 2 also shows the variation with temperature of thermal conductivities of transformer oils according to the results of other workers. The densities of these oils are given below:

Densities of Transformer Oils Tested by Various Workers

Name	Description	Density, g/cc, at 15° C
Kaye and Higgins . .	—	$0{\cdot}842_5$
Schmidt and Leidenfrost .	—	—
Tsederberg . . .	(*a*)	0·898
Tsederberg . . .	(*b*)	0·883
This work . . .	Allen's oil	0·873
This work . . .	MOW oil	0·892
This work . . .	IRO 2	0·885
This work . . .	IRO 3	0·867
This work . . .	IRO 5	0·878

No obvious correlation with density is apparent. The oil used by Kaye and Higgins has by far the lowest density and highest conductivity, and in this conforms to the correlation suggested by Cragoe [12] for petroleum liquids. Tsederberg has examined his results in terms of the relationship:

$$K = \frac{1}{\alpha} A C_p d^{4/3} M^{-1/3} = \frac{B}{\alpha} d^{4/3}$$

where $B = AC_p/M^{1/3}$ and is a constant for a given liquid.

A is a numerical constant equal to 1·5408 when K is in Kcal/M hr ° C and therefore to 0·0179 when in Jcm/cm² sec ° C.
C_p is the specific heat at 30° C
d is the specific gravity
M is the molecular weight
α is an association factor.

For the oils designated (*a*) and (*b*), C_p was 0·463 and 0·413 respectively, and, assuming them to be unassociated, with $\alpha = 1$, Tsederberg obtained agreements of within 2 per cent between his calculated and observed values over the range of temperature studied. Data for the other quantities would be necessary before the present oils could be checked with regard to this relationship.

P. W. L. Gossling [13] has commented on a possible correlation between the aromaticity of the three IRO oils and the change of thermal conductivity with temperature. The aromatic contents, in % wt, are quoted [11] as 27·0, 17·9, and 5·6 for oils 2, 5, and 3 respectively. The negative temperature coefficients are seen to increase in this order. He remarks that the Kaye and Higgins oil would be of low aromatic content and has a still greater negative temperature coefficient.

Whilst scope still remains for further detailed correlation, it is clear from the present results that the thermal conductivities of present-day transformer oils differ appreciably from those of oils available 30 years ago. A value of 0·00118 ± 0·00003 Jcm/cm² s °C (0·818 ± 0·021 Btu in/ft² h °F) now seems appropriate for the range 20° to 60° C (68° to 140° F).

ACKNOWLEDGMENTS

The authors are indebted to D. J. Hamblin for assistance with the measurements made of the voltage across the plates of the apparatus and to P. H. G. Allen, of the Transformer Engineering Department, The British Thomson-Houston Co. Ltd, Rugby, for supplying one of the oils investigated and for details supplied in discussion. They also wish to record their thanks to P. W. L. Gossling, of C. C. Wakefield and Co. Ltd, for his interest and helpful comments and for arranging for C. N. Thompson of "Shell" Research Ltd to supply the three oils from the IRO series.

The work described above has been carried out as part of the research programme of the National Physical Laboratory, and this paper is published by permission of the Director of the Laboratory.

References

[1] Challoner, A. R., and Powell, R. W. *Proc. Roy. Soc.*, **A**, 1956, **238**, 90.
[2] Markwood, W. H., and Benning, A. F. *Refrig. Engng*, 1943, **45**, 95.
[3] Powell, R. W., and Challoner, A. R. Tenth International Congress on Refrigeration, Copenhagen, Aug 1959, paper 2.7: *Mod. Refrig.*, 1960, **63**, 42.
[4] Riedel, L. *Chem. Ing. Tech.*, 1951, **23**, 321.
[5] Cherneyeva, L. *Khol. Naya Tek*, 1951, **28** (2), 22; 1952, **29** (3), 55; 1953, **30** (3), 60; 1955, **32** (1), 45.
[6] Allen, P. H. G. Amer. Soc. Mech. Engrs, "Thermodynamic and Transport Properties of Gases, Liquids, and Solids," Feb 1959, p. 350.
[7] Schmidt, E., and Leidenfrost, W. *Forsch. Geb. Ingwes.*, 1953, **19**, 65.
[8] Kaye, G. W. C., and Higgins, W. F. *Proc. Roy. Soc.*, **A**, 1928, **117**, 459.
[9] Tsederberg, N. V. *Teploenergetika*, 1957, **4** (2), 52.
[10] Griffiths, E. Iron and Steel Institute, Special Report No. 24, 1939, pp. 276, 280.
[11] Thompson, C. N. *J. Inst. Petrol.*, 1958, **44**, 295.
[12] Cragoe, C. S. "Thermal Properties of Petroleum Products," Bureau of Standards, Misc. Publ. No. 97, 1933.
[13] Gossling, P. W. L. Private communication.

IP STANDARDS

A Correction

The correct designation of the method for Rust Preventing Characteristics of Steam Turbine Oil which appears in the 19th edition of IP Standards for Petroleum and Its Products is IP 135/60. The terms in which the results are reported have been amended considerably from the previous versions.

Withdrawal of IP Methods

The Standardization Committee has decided that the following methods should be withdrawn from the 1961 Edition of IP Standards for Petroleum and its Products:

Carbon Disulphide Content—Method IP 108/57 Tentative. This method is being withdrawn because it is not applicable to the low concentrations of carbon disulphide encountered in petroleum products and does not appear to be used in the petroleum industry.

Spectrometric Analysis 1:3-Butadiene in C_4 Hydrocarbon Mixtures—Method IP 141/53 Tentative. This method has been found to be unreliable and inaccurate. It does not appear to be used in the United Kingdom. The ASTM Method that is technically equivalent is ASTM D1096-54. It is hoped that a satisfactory gas-chromatographic method will be developed for the determination of the impurities in 1:3-butadiene and published in a later edition of IP Standards.